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Shared and Individual-Specific Daily Stress-Reactivity in a Cross-Diagnostic At-Risk Sample

Robin N. Groen[1], Cara Arizmendi[2], Marieke Wichers[1], Marieke J. Schreuder[1], Kathleen M. Gates[2], Catharina A. Hartman[1], and Johanna T. W. Wigman[1]

[1] Department of Psychiatry, Interdisciplinary Center Psychopathology and Emotion Regulation, University of Groningen, University Medical Center Groningen

[2] Department of Psychology and Neuroscience, The University of North Carolina Chapel Hill

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Altered stress-reactivity may represent a general risk factor for psychopathology. In a broad at-risk sample, we examined (a) how stress and mild, daily expressions of psychopathology were interrelated over time, (b) whether we could detect subgroups with similar dynamics between stress and daily expressions of psychopathology (i.e., stress-reactivity), and (c) whether stress-reactivity was associated with psychopathology and social functioning. One hundred twenty-two young adults (43.4% women, mean age 23.6) at risk for developing a wide range of psychopathology completed a 6-month daily diary study. We used group iterative multiple model estimation (GIMME) to identify temporal associations between event stress and 11 mild expressions of psychopathology (e.g., feeling down, restlessness) at group, subgroup, and individual levels. Stress was associated with feeling irritated during the same day for >70% of individuals, and with feeling down and worrying during the same day for >50% of individuals. No stable subgroups characterized by similar daily stress-reactivity were identified. Instead, we observed 71 different stress-reactivity patterns in 122 individuals. Average daily event stress, but not overall stress-reactivity (weighted stress-response), was associated with psychopathology severity and social dysfunction. This study showed important similarities, as well as many differences between individuals, in terms of the impact of stress on mild expressions of psychopathology in daily life. Clustering based on similar stress-reactivity did not lead to stable subgroups. Finally, average daily stress levels, but not daily stress-reactivity, were associated with psychopathologic severity and social dysfunction. Findings highlight the importance of considering heterogeneity in stress-reactivity, but also challenges for identifying generalizable processes in doing so.

General Scientific Summary

Heightened reactivity to daily stressful events is considered a risk factor for reduced mental health. This study finds that daily stress-reactivity represents a complex process, characterized by general stress-reactivity processes that cross diagnostic boundaries, as well as highly individual patterns in terms of the total stress-response.

Robin N. Groen https://orcid.org/0000-0002-2863-6030
Cara Arizmendi https://orcid.org/0000-0001-5608-7385
Marieke J. Schreuder https://orcid.org/0000-0003-4901-2697
Johanna T. W. Wigman https://orcid.org/0000-0001-9504-4564

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The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Correspondence concerning this article should be addressed to Robin N. Groen, Department of Psychiatry, Interdisciplinary Center Psychopathology and Emotion Regulation, University of Groningen, University Medical Center Groningen, HPC CC72, Hanzeplein 1, Postbus 30.001, 9700 RB Groningen, the Netherlands. Email: r.n.groen@umcg.nl

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Altered emotional reactivity to daily stressful events is considered a risk factor for experiencing various types of psychopathology (Slavich, 2016; Wichers, 2014). Intensive longitudinal designs in which participants are repeatedly assessed for several days or weeks allow us to observe how the way that individuals react to daily life stressors is associated with experiencing psychopathology (Wright et al., 2020).

Studies using such designs have consistently shown altered patterns of emotional responses to daily life stressors in patients diagnosed with psychiatric disorders and in individuals at risk for psychiatric disorders. Alterations in stress-reactivity have most frequently been studied in association with psychotic and mood disorders. For example, compared with unaffected individuals, patients with current or remitted symptoms of psychosis (Klippel et al., 2018; Myin-Germeys et al., 2001, 2003; Palmier-Claus et al., 2012) or depression (Myin-Germeys et al., 2003; Van Winkel et al., 2015) show higher levels of negative affect and symptoms in response to stressors, as do individuals with subthreshold psychotic disorders (Lataster et al., 2009), and individuals with genetic, environmental, or psychometric risk of developing depression (Booij et al., 2018; Wichers et al., 2007) and psychosis (Klippel et al., 2018; van der Steen et al., 2017). Additionally, altered stress-reactivity has been associated with future symptoms, further supporting its role as a risk factor for psychopathology (Charles et al., 2013; Collip et al., 2013; Wichers et al., 2009). Because a large body of epidemiological studies has found stress exposure to increase the risk for many different psychiatric disorders (see, e.g., Berg et al., 2016; Cutajar et al., 2010; Gibson et al., 2017; Green et al., 2010; Hartman et al., 2019; McLaughlin et al., 2012; Oldehinkel & Ormel, 2015; Van Oudheusden et al., 2018) it seems plausible to hypothesize that daily exposure to stress and stress-reactivity may also represent a risk factor for psychopathology in general, rather than only for mood and psychotic disorders. However, this remains to be confirmed using intensive longitudinal designs.

Within this general risk-enhancing effect of stress-reactivity, it is likely that individual differences exist in the type of daily symptoms that are affected, just as these differences exist at the disorder level in epidemiology (i.e., not everyone develops the same disorder after stress exposure). Individual differences in daily stress-reactivity and the relevance thereof regarding outcomes are not fully understood yet. This is in part because earlier studies into stress-reactivity have either investigated a single, broad psychological response to stress (i.e., negative affect) in samples with different disorders, or investigated alterations in specific daily symptoms in response to stress in samples with one type of diagnosis. Earlier studies using a single psychological response to stress, reflecting negative affect (NA), have been conducted in samples with diverse psychopathology (see studies mentioned above) and therefore allow for comparisons across disorders in terms of NA stress-reactivity. However, NA is a broad construct, measured by averaging multiple affective states (e.g., anger, sadness) that each may differ in duration and frequency (Verduyn & Lavrijsen, 2015). Hence if NA is increased in response to stress in individuals diagnosed with different disorders (i.e., depression vs. anxiety) it is unclear what specific symptoms drive this NA reactivity. Additionally, studies do not always use the same items to measure NA, thus limiting comparability. Hence, the extent to which individuals with different vulnerabilities or clinical diagnoses resemble each other in terms of associations between stress and specific components of negative affect (e.g., feeling irritated or anxious) has remained unexplored. Some studies have investigated changes in distinct daily expressions of psychopathology in response to stress. For example, Collip and colleagues (2013) and Palmier-Claus and colleagues (2012) found that daily psychotic-like experiences increased in response to stress in individuals at risk for psychosis or in individuals with a psychotic disorder. However, because these studies did not consider other types of distinct daily expressions of psychopathology or other psychopathological outcomes, the findings do not inform us on whether individual differences in stress-reactivity in terms of psychotic symptoms reflect a psychosis-specific or more general risk factor. These examples show that the current state of knowledge on individual differences in daily life stress-reactivity and how these are related to psychopathological outcomes may be enhanced by considering multiple, distinct daily expressions of psychopathology simultaneously in individuals experiencing different types of psychopathology.

Although we emphasize the need to understand individual differences in stress-reactivity, at the same time it is unlikely that every individual is unique. Thus, we anticipate that commonalities in stress-reactivity also exist. Research investigating commonalities in temporal symptom patterns across individuals who experienced different types of mental health problems has scarcely been conducted (e.g., Wigman et al., 2015). It is therefore unclear whether commonalities in stress-reactivity are likely to be syndrome specific or rather differentiate between individuals based on psychopathology severity. There is support for both types of clustering. Wigman and colleagues (2015) analyzed temporal patterns of mental states in a pooled ecological momentary assessment dataset made up of samples of individuals with psychosis, depression, and unaffected comparison subjects. They found that individuals with psychosis were more likely to have stronger associations between feeling suspicious and other mental states than unaffected individuals and individuals with depression. Even though Wigman and colleagues did not investigate stress-reactivity, their results suggests that some qualitatively different temporal symptom patterns that are diagnosis specific may be expected. Although data-driven subgrouping approaches (e.g., latent class techniques) that are commonly applied to cross-sectional data frequently identify subgroups that reflect severity differences rather than qualitatively different symptom patterns (Van Loo et al., 2012), it is yet unclear whether this also applies to intensive longitudinal data. However, there is some empirical support suggesting that subgroups based on temporal dynamics would reflect severity differences. Studies

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that included unaffected, at-risk, and clinically affected individuals suggested that stress-reactivity may reflect risk in a dose-response fashion (Booij et al., 2018; Klippel et al., 2018; Lataster et al., 2009). Thus, the evidence is inconclusive as to how commonalities in stress-reactivity exist in the population.

The challenge is thus to examine whether smaller subgroups that share similar within-person processes exist (Ernst et al., 2020; Wright et al., 2019) and what these subgroups are based on. This information could help us to understand how stress leads to divergent trajectories (Nolen-Hoeksema & Watkins, 2011): that is, why some individuals experience depressive symptoms after stressful events, while others experience psychotic symptoms or no symptoms at all. Previously used multilevel approaches provide estimates of average within-person effects, and to some extent expose the between-person differences with respect to these associations. Additionally, these models assume within-group homogeneity, meaning that associations between stress and every psychopathological symptom are assumed present for each individual in the sample. Although these models are thus suitable for providing a general picture of what is going on, they provide little insight into which within-person processes involving specific symptoms are shared by parts of the sample. The recently developed subgrouping extension of Group Iterative Multiple Model Estimation (S-GIMME; Gates et al., 2017) is able to achieve this. This reliable model building procedure identifies whether within-person associations, at the same moment and over time, are shared by the whole group, by subgroups or are unique to an individual, without assuming within-group homogeneity (Lane et al., 2019).

This study explored individual differences in stress-reactivity in individuals with heightened risk for psychopathology. Our first aim was to explore which changes in mild, daily expressions of psychopathology in response to stress are more general (i.e., similar processes that are found in the majority of people), which responses are shared by distinct subgroups, and which responses are person-specific. Our second aim was to evaluate whether similarities in stress-reactivity (i.e., subgroups of individuals with similar patterns of stress-reactivity) would be accompanied by shared outcomes, that is, symptom severity or the type of psychopathology that is experienced. To do this, we analyzed individual time series data of young individuals at risk for mental health problems, collected in a six-month daily diary study, using S-GIMME. Regarding our first aim, we expected that some pathways between stress and mild, daily expressions of psychopathology would apply to the large majority of individuals, that meaningful subgroups could be identified that differed in terms of these pathways and that some pathways would be only applicable to one individual. Regarding our second aim, we hypothesized based on the available empirical evidence that subgroups may either reflect severity differences (e.g., no symptoms vs clinical symptoms or with different levels of social functioning) or could show some psychopathology specificity (e.g., depressive symptoms).

Method

Sample and Procedure

Data come from the TRAILS-TRAND-ID study (Schreuder et al., 2020), which investigated the day-to-day dynamics of psychopathology in young adults at risk for developing mental health problems. The TRAILS TRANS-ID study consisted of a six-month daily diary study and three interviews, which occurred prior to (i.e., baseline interview), directly after (i.e., post interview), and one year after (i.e., follow-up interview) the diary period. The TRAILS TRANS-ID study was designed to be able to capture a period of symptom development. To maximize the possibility of observing changes in symptomatology and simultaneously minimizing participant burden, a six-month daily diary design was conducted. Participants received a text message on their smartphones with a link to an online daily diary questionnaire at a fixed time every evening (based on their personal preference) for a period of six consecutive months. Participants were asked to complete the diary as quickly as possible but had a window of three hours in which they could respond to the prompt. The daily diary was administered and stored via a secure in-house service provider: Roqua (www.roqua.nl). For more details on the design, procedure, and sample characteristics, see Schreuder et al. (2020) and Groen et al. (2022).

We used data from the 122 participants (M_{age} = 23.6 years, SD_{age} = .7; 56.6% male) of the TRAILS TRANS-ID sample who completed at least 60 of the daily diary assessments (i.e., minimum recommended observations to perform GIMME; Lane et al., 2019) and the post interview. These young adults were part of the clinical cohort of the ongoing, epidemiological Tracking Adolescents' Individual Lives Survey study (TRAILS-CC). Participants of TRAILS-CC (and thus of TRAILS TRANS-ID) are considered to have a heightened risk for experiencing mental health problems because they have been in contact with psychiatric services before the age of 11 (see Oldehinkel et al., 2015 for a detailed cohort description). All participants provided written informed consent and the Medical Ethical Committee of the University Medical Center Groningen granted approval (2017/203) for this study.

Measures

Daily Assessed Domains of Psychopathology

The daily questionnaire contained 58 questions assessing psychopathology and resilience. Diary questions concerned both positive and negative affective states and behaviors, as well as questions concerning physical problems, event appraisals and drug- and alcohol use (see online supplemental materials for the complete questionnaire). Questions were derived from earlier studies that adopted ambulatory assessments or diary protocols (i.e., Kramer et al., 2014; Krieke et al., 2016; Rosmalen et al., 2012; Van Roekel et al., 2017) and from existing questionnaires such as the Symptom Checklist (SCL-90; Derogatis & Cleary, 1977), the Adult Behavior Checklist (ABCL; Achenbach & Rescorla, 2003), and the Positive and Negative Affect Scale (PANAS; Watson et al., 1988). Questions were included as diary items if they (a) were relevant to multiple diagnostic categories; (b) were sufficiently distinct from other items; (c) were likely to vary from day to day; and (d) were comprehensible. We checked the comprehensibility of the questions during a pilot study with individuals who had a similar educational attainment level as the participants (see Schreuder et al., 2020; for more details about the daily questionnaire development). Diary questions were phrased so that they were not so extreme as to have problematically low endorsement on a daily basis. Therefore, responses to these diary questions reflect mild, daily expressions of psychopathology.

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We selected 11[1] questions (shown in Figure 1) about various psychopathology domains (e.g., depressive and attention deficit hyperactivity disorder symptoms) and perceived stress ("I felt stressed"). Participants were asked "To what extent did you feel ____ today?" in which the blank was filled with one of the diary questions (e.g., "restless"). Using a slider, they could then indicate their response to these questions on a Visual Analogue Scale (VAS) ranging from 0 *not at all applicable* (left) to 100 *very much applicable* (right). Schreuder et al. (2020) showed that diary questions were associated with corresponding psychopathology domains (e.g., I felt down was associated with the depressive disorder domain of the clinical interview) that were assessed with the short version of the Schedules for Clinical Assessment in Neuropsychiatry (SCAN; Wing et al., 1990; see details below). On average, these 11 items were .32 (range .17–.42) correlated with corresponding domains. This was with the exception of the item "I felt suspicious," which, unlike in previous studies (Oorschot et al., 2009; Thewissen et al., 2008), was not found to be correlated with the psychosis domain in this study. This is likely attributable to the fact that psychotic symptoms that are assessed in the clinical interview are much rarer (i.e., visual and auditory hallucinations), as compared with the daily manifestations of subthreshold psychotic experiences such as paranoia, which are more common (Van Os et al., 2009) and are also associated with other psychopathology (Varghese et al., 2011).

Daily Stressful Event

Consistent with previous stress-reactivity research (Klippel et al., 2018; Vaessen et al., 2017, 2019; van Nierop et al., 2018), we conceptualized daily stressful events by using subjectively evaluated unpleasantness of daily negative events.[2] Participants were asked to think about the most important negative event of that day, and to report how unpleasant that event had been using a VAS ranging from *not at all* to *very much*. Participants' responses to this question provided a continuous measure that reflected the extent to which they had experienced a stressful event each day. In line with previous work, we labeled this "event stress" (Klippel et al., 2018; van Nierop et al., 2018).

Dimensional Psychopathology Assessment—Clinical Diagnostic Interview

The short version of the Schedules for Clinical Assessment in Neuropsychiatry (SCAN; Wing et al., 1990), the mini-SCAN (Nienhuis et al., 2010) was conducted to dimensionally assess psychopathological symptoms. At the post interview, the mini-SCAN questions pertained to the period of six months diary period. Trained interviewers rated symptoms of the following psychiatric disorders: mood, anxiety, psychotic, substance use, attention deficit hyperactivity disorder (ADHD), and autism spectrum disorders (ASD) on a 3-point scale (*absent* [0], *subclinical* [1], *clinical* [2]). To assess oppositional or antisocial behavior, interviewers orally assessed the 15-item aggressive behavior subscale of the Adult Self-Report (Achenbach & Rescorla, 2003) using the same 3-point scale.

Social Functioning

We assessed functioning with the 45-items Groningen Questionnaire of Social Behavior (GVSG; de Jong & Van Der Lubbe, 2001). The GSVG assesses multiple domains of functioning, including social relationships, work, and school. Using a 4-point scale (*never*, *sometimes*, *often*, and *always*), participants reported how often a specific situation (e.g., "I could not get along with my parents") had occurred during the last six months (i.e., the diary period). Cut-off scores (de Jong & van der Lubbe, 2001) were used to determine whether functioning was not impaired, mildly impaired, or severely impaired.

Statistical Analyses

Intraclass Correlation

To examine the proportion of variance explained by the between- and within-person level of the data, we calculated the intraclass correlation (ICC= $\sigma^2_{between}/[\sigma^2_{between} + \sigma^2_{within}]$). The ICC varies between 0 and 1. An ICC close to 1 suggests that almost all variance in individuals' responses is attributable to between-person differences. ICCs closer to 0 suggest greater within-person variation.

Stress-Reactivity

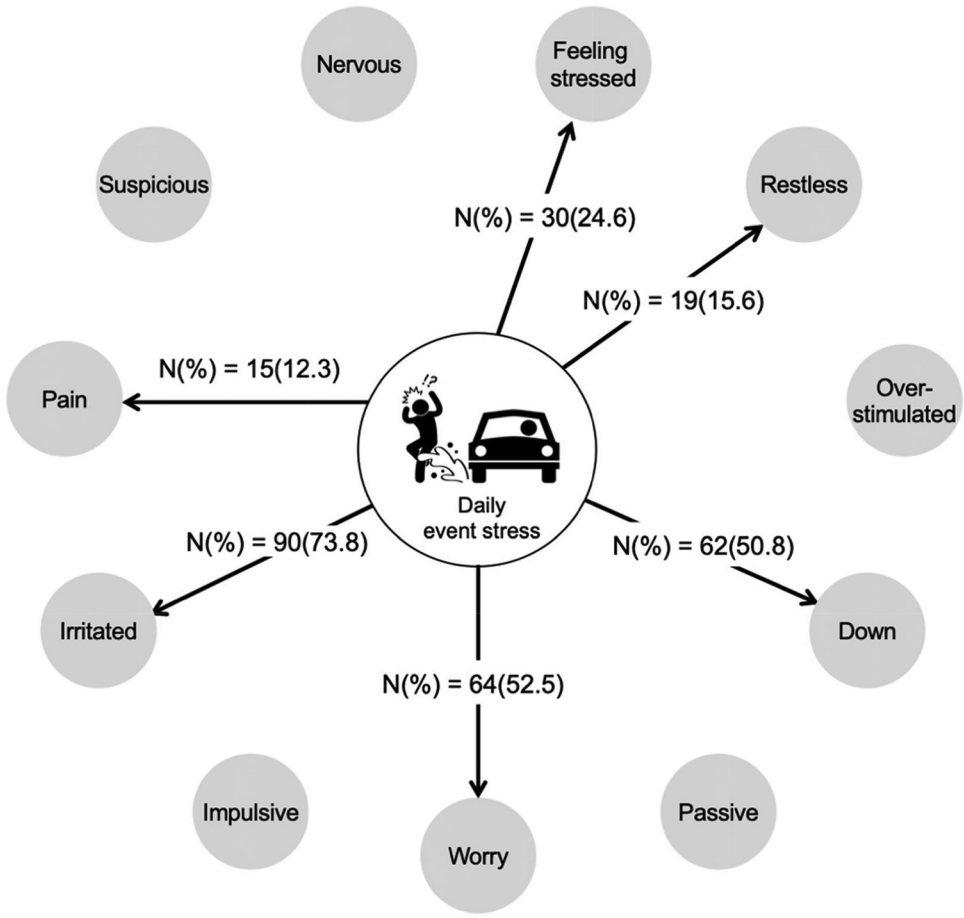
We used subgrouping GIMME to model contemporaneous and (cross)lagged associations between daily stressful events and mild, daily expressions of psychopathology present at the group, subgroup, and individual level. GIMME is an algorithm that uses unified structural equation modeling (uSEM; Kim et al., 2007) in an iterative model fitting procedure, which involves several steps to obtain the best fitting model for each individual (Gates & Molenaar, 2012). The associations in these final individual-specific model are then estimated simultaneously (S. Wright, 1934). USEM is a variant of structural vector autoregressive modeling and simultaneously estimates both directed contemporaneous and first-order lagged associations between variables. Directed contemporaneous effects reflect the association between two variables during the same day, and may surface when the process of interest changes faster than the time interval that is assessed (i.e., over

[1] This is a deviation from preregistration, in which we had registered to use 16 mild, daily expressions of psychopathology (i.e., diary questions with negative valence) to investigate differences in the type (i.e., which daily symptom increased) of stress-reactivity. To reduce model complexity and facilitate interpretation of the results, we decided to remove six items from the model. We removed those items that were either a synonym of one of the other items (e.g., "My thoughts would not leave me alone" was too similar to "I worried") or were considered to be a worse indicator of a specific symptom domain than another item (e.g., "I felt down" instead of "I had trouble making decisions" to represent depressive symptoms). We evaluated the quality of the indicator both on the content of the item and its correlation with corresponding domains assessed with the semi-structured clinical interview. See section 1 "1. Preregistration and deviations" on page 2 of the online supplemental materials for more details and Table S1 in the online supplemental materials for the complete list of items used in the study.

[2] This is a deviation from the preregistration, in which we registered that we would use responses to the question "I felt stressed" as measure of daily stress. Because "feeling stressed" may already reflect a specific type of reactivity to a negative event and we were interested in differences in various types of reactivity to negative events, we instead used the diary question which inquired participants' subjective appraisal of daily negative events. Moreover, this operationalization of stressful events is the same as those used in previous ecological momentary assessment studies investigating stress-reactivity (e.g., Myin-Germeys et al., 2001; Vaessen et al., 2017), allowing to compare our findings with those of previous studies.

Figure 1

Graphical Display of the Most Frequently Observed Associations (i.e., in More Than 10% of Individuals) Between Daily Event Stress and the 11 Mild, Daily Expressions of Psychopathology



Note. Event stress represents the stressfulness of an event, which was conceptualized as the subjectively appraised unpleasantness of negative events. All lines represent contemporaneous associations. See Table 3 for the frequencies of all estimated contemporaneous and lagged psychopathological responses to daily event stress.

hours instead of days; Granger, 1988). Lag(1) effects reflect the association between a variable measured at *time t* (today) and the same (i.e., autoregressive effect) or another variable (i.e., cross-lagged effect) at *time t* + 1 (tomorrow). To model stress-reactivity, we treated the item "event stress" as an exogenous variable (Arizmendi et al., 2021). Thus, "event stress" could predict the 11 psychopathology domains contemporaneously and over time but could not be predicted by these domains.

In Step 1 of S-GIMME, a null model in which all coefficients (except for the autoregressive effects) are fixed at zero is fit to the time-series data of each individual. This allows to obtain modification indices (MIs) associated with each estimated parameter, which indicate whether freeing that parameter will significantly improve model fit for that individual. Statistical significance here is determined using a Bonferroni-corrected $\alpha = .05/N$, where N represents the number of individuals in the sample. For our analyses, the alpha level was thus .00041. This rather conservative alpha value protects against overfitting. Subsequently, the parameter (path) with the highest MI that is significant for a prespecified proportion of individuals (i.e., a 51% cut-off) is added to the group-level model and thus considered a group-level association. This procedure is repeated until no path is found to be significant for the predetermined cutoff value of individuals. A pruning procedure is then applied to remove paths that are not significant any longer for the majority (preestablished proportion) of individuals. At the end of the group-level model phase, the model is estimated for each participant using the group-level model as a starting model (i.e., a model with all coefficients at zero except for the autoregressive effects and group-level parameters).

In the second step, similarities between participants are established based on two sources: individual coefficient estimates of the paths in the group-level models and estimates of each individual's expected parameter change, indicating which individual-level paths can be added for that person. Using the walktrap algorithm (Pons & Latapy, 2006) subgroups are identified based on similarities in these individual-level estimates. Subgroup-level paths are

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then identified following a similar procedure as the group-level model search, but now paths significant (again using a Bonferroni-corrected alpha level: $\alpha = .05/N$) for the majority of participants (i.e., 51%) within each subgroup are estimated.

In the final step, models containing group- and subgroup-level paths are considered the null model and significant individual-level paths are freed/identified until the model fit for a given individual has reached excellent fit according to at least two of four indices (Brown, 2015): comparative fit index (CFI) $\geq .95$; non-normed fit index (NNFI) $\geq .95$; root mean squared error of approximation (RMSEA) $\leq .05$; standardized root mean residual (SRMR) $\leq .05$. In the individual-level modeling step, a path was considered significant at $p < .01$. The final individual level models, thus, contain group-level, subgroup-level and individual-level paths. While the group-level paths are estimated for all individuals and the subgroup paths for all individuals who were assigned to the same subgroups, individual-level paths may be only estimated for that specific individual. Gates et al. (2017) showed that using this stepwise procedure to finally obtain an individual-level model for each person greatly improved the recovery of paths at the individual level.

Prior to model estimation, time-series for each variable and individual were detrended. GIMME uses full information maximum likelihood (FIML) to accommodate missing data.

General, Subgroup, and Individual Responses to Stress

We used output from the individual models (containing group-, subgroup- and individual-level associations) to summarize which within-person responses to stress were general, subgroup- or individual-specific. For each individual there are 22 potential paths (11 contemporaneous and 11 lagged) between event stress and each daily symptom. Note that not all potential paths are in fact estimated as the iterative procedure ensures that only paths that significantly improve the fit of an individual's model will become part of the individual's final model. In the final model for each individual, all paths that improve their model are estimated simultaneously (Wright, 1934). We summarized how many estimated paths per person were significant, and which paths were most frequently estimated. Participants' overall stress-reactivity was conceptualized as the sum of the coefficients of individuals' significant contemporaneous[3] stress paths divided by the number of possible stress-psychopathological response paths (i.e., 11 paths). As such, we obtained a weighted estimate per person that reflected the combined number and strength of the participants' psychopathological response to stress. This is conceptually similar to node out-strength, a measure that is used in network models to reflect the influence a node has on other nodes in the network (Wasserman & Faust, 1994).

We performed two exploratory analyses. We investigated whether participants who are more reactive to stress (i.e., have more and stronger associations between daily stress and daily expressions of psychopathology) reported (a) worse social functioning and (b) more psychopathology. To this end, we performed two separate linear regressions with stress out-strength as a predictor of (a) social functioning (GVSG) and (b) psychopathology severity (total mini-SCAN mean domain severity) as respective outcomes. These analyses were adjusted for the following covariates: sex, educational attainment (1, elementary; 6, university) and parental social economic status (combined measure of income, education and occupation). For the rationale and operationalization of the covariates, see the online supplemental materials (Bolger et al., 1989; Gallo et al., 2006; Ganzeboom & Treiman, 1996; Grzywacz et al., 2004; Jahnel et al., 2019; Kessler et al., 2005; Kolla et al., 2016; Kuehner, 2003; Loomes et al., 2017; Molnar et al., 2008; Mulder et al., 2011; Myin-Germeys et al., 2003; Newacheck et al., 2003; Russell et al., 2016; Santiago et al., 2011; Sheets & Armey, 2020; van der Linden et al., 2021; Wang et al., 2017). In a second step, we adjusted each model for average levels of event stress during the diary study, to determine the relative contribution of stress-reactivity in predicting social functioning and psychopathology severity. We used a Bonferroni-corrected alpha ($\alpha = .05/N$), where N was the number of predictors. Step 1 of the regression model contained four predictors, setting alpha at .013, whereas Step 2 contained five predictors setting alpha at .01.

Evaluation of Subgroup Stability

In line with previous applications of S-GIMME (Dajani et al., 2019; Ellison et al., 2020), we evaluated the robustness of the subgrouping solution (Gates et al., 2019).[4] The procedure and results are described in detail in the online supplemental materials (Karrer et al., 2008; Meilă, 2007).[5]

Results

Approximately 25% of the participants met criteria for a psychiatric diagnosis during the post interview (Schreuder et al., 2020). Table 1 shows for which diagnoses criteria were met and displays average scores for each section of the mini-SCAN and GVSG. In total, the 122 participants completed 20245 assessments. Average compliance was 88.5% or 162.3 of the daily diaries (SD = 9.8%, range = 59.6% to 100%, SD = 17.5, range in days = 75–189).[6] When a diary was completed, all questions on that day were completed, as it was not possible to skip questions. We observed variability within and between participants in daily measured event stress and the 11 mild, daily expressions of psychopathology. Table 2 shows the descriptive statistics for the daily diary questions. As presented in Table 2, the ICC for the daily expressions of psychopathology varied between .32 ("I could not bring myself to do anything") and .54 ("I felt suspicious"). For most diary questions, the variation within participants was bigger than the variation between participants. Average within-person bivariate correlations between all daily measured variables and visual representations of spread of

[3] We focused on contemporaneous paths because these paths made up 90% of the estimated paths. We did not combine contemporaneous and lagged paths, because their interpretation differs.

[4] After completion of our preregistration, we learned about the studies by Ellison et al. (2020) and Dajani et al. (2019). Both studies observed subgroups obtained with S-GIMME that were not stable, we therefore added this step to our analytic plan. This analysis was not preregistered.

[5] The stability check for the subgrouping solution showed that subgroups were not stable. Therefore, we did not further investigate whether subgroup membership was associated with social functioning, and psychopathology type and/or severity. This is a deviation from our preregistration.

[6] Compliance for the total diary sample, including the individuals who dropped out during the daily diary study and did not complete the post-interview, was: 83.2% or 152.2 of the daily dairies (SD = 20.9%, range = 4.9% to 100%, SD = 38.3 diaries, range = 9–189 diaries).

Table 1
Sample Characteristics (i.e., GVSG and Mini-SCAN Assessed at the Post Interview)

Measure	*N* = 122
GVSG impairments (0 = *healthy*, 1 = *subclinical*, 2 = *clinical)*; (*M*, *SD*)	
Parents	0.3 (0.6)
Partner	0.6 (0.8)
Children	0.4 (0.7)
Friends	0.5 (0.6)
Education	0.5 (0.6)
Occupation	0.8 (0.8)
Household	0.7 (0.7)
Spare time	0.9 (0.8)
Mini-SCAN diagnoses (*N*, %)	
Anxiety disorder	12 (9%)
Attention deficit and/or hyperactivity disorder	8 (7%)
Mood disorder	23 (19%)
Psychotic disorder	5 (4%)
Substance use disorder	4 (3%)
Mini-SCAN domain scores (0 = healthy, 1 = subclinical, 2 = clinical); (*M*, *SD*)	
ADHD	0.7 (0.4)
Anxiety	0.2 (0.3)
ASD	0.4 (0.4)
Depression	0.4 (0.4)
Mania	0.2 (0.2)
ODD	0.4 (0.3)
Psychotic	0.0 (0.1)
Substance use	0.2 (0.2)
Tension	0.6 (0.5)

Note. GVSG = Groningen Questionnaire of Social Behavior; Mini-SCAN = short version of the Schedules for Clinical Assessment in Neuropsychiatry; ADHD = attention deficit hyperactivity disorder; ASD = autism spectrum disorder; ODD = oppositional defiant disorder.

person-means and average within-person SD's can be found in online supplemental Table S2 and Figures S1 and S2, respectively.

GIMME Results

All person-specific models converged normally and fit the data well for all participants, with mean fit indices: CFI = .95, NNFI = .93, RMSEA = .039, SRMR = .066. Six sample-level contemporaneous paths (i.e., significant for >51% of the sample) emerged, of which one involved event stress. Each of these paths emerged after controlling for the lagged influence of the target variable on itself. Event stress predicted feeling irritated on the same day for 73.8% of the individuals. The other five group-level effects were: (a) restlessness → feeling down, (b) restlessness → feeling overstimulated, (c) worrying → perceived stress, (d) perceived stress → nervousness and (e) perceived stress → restlessness. The group-level network and frequencies of all group-level paths are displayed in the online supplemental materials (Figure S1 and Table S3). Subgroups obtained with S-GIMME were not stable (results of the evaluation procedure are described in the online supplemental materials). Therefore, we did not explore these subgroups further.

Shared and Individual Stress-Reactivity

To evaluate which associations between event stress and mild daily expressions of psychopathology were shared between participants in addition to the group-level path, we pooled the individual-level model results, which are based on group-level, subgroup-level, and individual-specific path estimations. Individual-level models of 118 participants (96.7% of the sample) contained at least one significant association between event stress and one of the 11 psychopathology domains. Of the 343 estimated psychopathological associations with stress that were nonzero in the 118 individual-level models, 311 (90.6%) reflected contemporaneous associations between event stress and specific psychopathology domains. The majority (95.6%) of psychopathological associations with event stress were positive, indicating that more event stress was associated with higher (mild) daily expressions of psychopathology.

Figure 1 depicts the associations between psychopathology and event stress that were observed for at least 10% of individuals, which were all contemporaneous. All paths from event stress to psychopathology domains are listed in Table 3. Besides the contemporaneous path from event stress to irritated, two paths were observed in more than 50% of individuals: event stress to

Table 2
Means, Standard Deviations, Mean Ranges, and Intraclass Correlation for Mild, Daily Expressions of Psychopathology and Negative Event Stress for the Subset Who Participated (n = 122)

Item	*M*	b*SD*	w*SD*	Range	ICC
I felt suspicious (suspicious)	11.7	11.2	8.4	0.1−54.5	0.54
I could not bring myself to do anything (passive)	18.4	11.5	15.3	0.6−60.4	0.32
I worried (worrying)	21.6	14.3	14.6	0.6−79.1	0.45
I was irritated (irritated)	17.0	11.7	13.5	0.6−60.8	0.38
I experienced pain (backpain, headache, tummy ache, etc.) (pain)	17.5	14.1	13.8	1.3−67.4	0.47
I felt overstimulated (overstimulated)	17.3	15.0	12.5	0.4−68.1	0.53
I felt restless (restless)	19.5	13.7	13.6	0.5−62.0	0.45
I felt stressed (perceived stress)	18.9	13.9	13.9	0.6−61.1	0.44
I acted impulsively (impulsivity)	20.7	15.5	12.9	0.2−69.3	0.53
I felt down (down)	15.6	13.7	12.2	0.5−66.6	0.49
I felt nervous (nervous)	15.4	11.8	12.8	0.6−55.2	0.40
Think of the most important negative event that occurred today. How unpleasant was this event? (event stress)	23.5	13.8	17.5	1.2−83.8	0.35

Note. *M* = mean of all person-means; b*SD* = standard deviation from the average person-mean; w*SD* = mean of all within-person standard deviations. Intraclass correlation (ICC) was calculated using the formula $\sigma^2_{between}/(\sigma^2_{between} + \sigma^2_{within})$. See Figures S1 and S2 in the online supplemental materials for a visual representation of the *M* and w*SD*, respectively.

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Table 3
Number of Participants (N) With and Mean Coefficients (SD) of the Significant Concurrent and Lagged Paths of Event Stress → Mild Expressions of Psychopathology

Concurrent and Lagged Paths[a] Event Stress → Mild Expressions of Psychopathology			*N* (%)	Mean Coefficient (*SD*)
$Stress_t$	→	$Irritated_t$	90 (73.8)	0.31 (0.15)
$Stress_t$	→	$Worry_t$	64 (52.5)	0.34 (0.14)
$Stress_t$	→	$Down_t$	62 (50.8)	0.38 (0.17)
$Stress_{t-1}$	→	$Stress_t$	45 (36.9)	0.26 (0.11)
$Stress_t$	→	Perceived $stress_t$	30 (24.6)	0.43 (0.18)
$Stress_t$	→	$Restless_t$	19 (15.6)	0.29 (0.1)
$Stress_t$	→	Physical $pain_t$	15 (12.3)	0.3 (0.08)
$Stress_t$	→	$Suspicious_t$	9 (7.4)	0.33 (0.1)
$Stress_t$	→	$Nervous_t$	7 (5.7)	0.26 (0.04)
$Stress_t$	→	Passive	7 (5.7)	0.18 (0.22)
$Stress_{t-1}$	→	$Irritated_t$	6 (4.9)	−0.07 (0.27)
$Stress_{t-1}$	→	$Down_t$	5 (4.1)	0.13 (0.26)
$Stress_t$	→	$Overstimulated_t$	5 (4.1)	0.32 (0.12)
$Stress_{t-1}$	→	$Overstimulated_t$	5 (4.1)	0.03 (0.23)
$Stress_{t-1}$	→	$Suspicious_t$	5 (4.1)	0.11 (0.23)
$Stress_t$	→	$Impulsive_t$	3 (2.5)	−0.09 (0.26)
$Stress_{t-1}$	→	$Restless_t$	3 (2.5)	0.11 (0.21)
$Stress_{t-1}$	→	Passive	2 (1.6)	−0.02 (0.41)
$Stress_{t-1}$	→	$Worry_t$	2 (1.6)	0.37 (0.07)
$Stress_{t-1}$	→	Perceived $stress_t$	1 (0.8)	0.11 (NA)
$Stress_{t-1}$	→	$Impulsive_t$	1 (0.8)	0.25 (NA)
$Stress_{t-1}$	→	$Nervous_t$	1 (0.8)	0.2 (NA)
$Stress_{t-1}$	→	Phyiscal $Pain_t$	1 (0.8)	0.23 (NA)

Note. *N* of analyzed sample = 122 participants. NA = not applicable.
[a] These paths are derived from the individual-level models, which contain group-level, subgroup-level, and individual-specific paths.

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feeling down and to worrying. The most frequently observed lagged association was the effect of event stress on feeling irritated the next day and was observed in six (5%) individuals. Ten associations with event stress were person-specific in this sample (i.e., present in only one person or person-specific direction). When taking all associations with event stress into account, we found that the 122 individuals showed 71 different combinations of non-null stress paths (Figure S2 in the online supplemental materials). Thus, persons vary substantially in terms of their stress-reactivity.

Stress-Reactivity and Secondary Outcomes

Because no stable subgroups were identified, secondary outcomes were not compared between subgroups. Separate models were run with and without average daily event stress to determine the relative contribution of average daily event stress and participant's total stress-reactivity (i.e., stress out-strength) in predicting social functioning and psychopathology severity postdiary. Table 4 presents the two linear regressions for each outcome variable. Participants' average level of daily event stress, but not their stress-reactivity, was associated with greater severity of psychopathology and lower social functioning.

Discussion

This study investigated to what extent daily stress-reactivity represents a general, a subgroup-specific or an individual-specific process in a sample of $N = 122$ young adults at risk for psychopathology. To this end, we modeled daily stressfulness of events (event stress) as an exogenous variable predicting 11 distinct, mild, daily expressions of psychopathology. We found that approximately 90% of the non-null associations between stress and psychopathology were contemporaneous (i.e., during the same day). This indicates that stress-reactivity processes mostly occur within the 24-hr interval at which we measured (Granger, 1988). On days with more event stress than usual, the vast majority of participants reported higher levels of (mild) psychopathology. Of this majority, most individuals reported to feel more irritated, worried and down on days with more experienced stress than usual. As these paths involve psychopathology domains that are expressed in multiple disorders, these associations may thus represent general, rather than domain-specific, aspects of the stress-reactivity process.

At the same time, we observed considerable heterogeneity in stress-reactivity. When considering all the paths from stress to mild, daily expressions of psychopathology (i.e., contemporaneous and lagged) and differentiating between positive and negative associations, 71 different combinations of paths were detected in 122 young adults. With our data-driven subgrouping approach, in which we investigated multiple domains of mild daily expressed psychopathology, and studied a sample with diverse psychopathology we did not uncover direct evidence for subgroups based on similar stress-reactivity patterns. Our results thus tell two stories: one about common aspects of daily stress processes and one about vast differences between people in daily individual stress-reactivity. Finally, we showed that individuals' total stress-reactivity was not associated with psychopathology severity or social dysfunction, but their average stress level was. Thus, we did not find support that stress-reactivity reflects a dimensional risk for psychopathology. Instead, the current results suggest that stress-reactivity was present regardless of the presence of any psychological disorder, the type of disorder, and social functioning.

Table 4
Total Stress-Reactivity Predicting Social Functioning and Psychopathology Severity

Model	Social functioning (GVSG)			Psychopathology severity (mini-SCAN)		
	B [95% CI]	β [95% CI]	*SE* [*B*]	*B* [95% CI]	β [95% CI]	*SE* (*B*)
Step 1						
Total stress-reactivity[a]	1.12 [−0.04, 2.27]	0.18 [−0.01, 0.36]	0.58	4.33 [−3.87, 12.53]	0.09 [−0.08, 0.27]	4.14
Sex	−0.05 [−0.15, 0.05]	−0.18 [−0.56, 0.2]	0.05	−0.92 [−1.62, −0.21]	−0.48 [−0.84, −0.11]	0.36
Educational attainment young adult	−0.04 [−0.09, 0.01]	−0.15 [−0.33, 0.04]	0.02	−0.43 [−0.76, −0.09]	−0.22 [−0.4, −0.05]	0.17
Parental SES	−0.03 [−0.09, 0.04]	−0.08 [−0.26, 0.1]	0.03	−0.02 [−0.49, 0.46]	−0.01 [−0.18, 0.17]	0.24
Adjusted R^2		0.04			0.08	
Step 2						
Total stress-reactivity[#]	1 [−0.07, 2.07]	0.16 [−0.01, 0.33]	0.54	3.45 [−4.04, 10.95]	0.07 [−0.09, 0.23]	3.78
Average daily event stress	**0.01 [0, 0.01]**	**0.39 [0.22, 0.56]**	0.002	**0.06 [0.03, 0.08]**	**0.4 [0.24, 0.56]**	0.01
Sex	0 [−0.1, 0.09]	−0.02 [−0.38, 0.34]	0.05	−0.6 [−1.26, 0.05]	−0.31 [−0.65, 0.03]	0.33
Educational attainment young adult	−0.03 [−0.08, 0.01]	−0.12 [−0.29, 0.05]	0.02	−0.38 [−0.69, −0.07]	−0.2 [−0.36, −0.03]	0.16
Parental SES	−0.04 [−0.1, 0.02]	−0.11 [−0.28, 0.05]	0.03	−0.12 [−0.56, 0.31]	−0.05 [−0.21, 0.11]	0.22
Adjusted R^2		0.18			0.23	

Note. GVSG = Groningen Questionnaire of Social Behavior; mini-SCAN = short version of the Schedules for Clinical Assessment in Neuropsychiatry.
[a] This was calculated as participants' total stress-reactivity / 11 (i.e., the number of possible significant contemporaneous paths). This is similar to network centrality measure: out-strength. Boldface type indicates effects that are statistically significant at a Bonferroni-corrected α level: $\alpha = .05/N$, where N is the number of predictors. Definitions and rationale for the covariates: sex (0, female; 1, male), participants' educational attainment, and parental SES, can be found in the online supplemental materials on page 4.

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Zooming in on the most commonly shared stress-psychopathology paths, we noticed these involved affect-related domains, rather than behavioral domains (i.e., being impulsive or being passive). Because within-person means and within-person variability were similar for the affect- and behavioral psychopathology domains, these differences in association with stress cannot be attributed to behaviors being less reported in daily life. Therefore, we speculate that if daily stressors have an impact on behavior, this may not occur via a direct behavioral effect, but rather through changes in affect. The finding that the majority of individuals reporting feeling more irritated, worried, or down on days with more event stress raised the question to what extent these paths may represent adaptive functioning. For instance, worrying about an unpleasant event can be functional: it may push us to find a solution for a problem. However, when the extent of worrying is disproportional to the impact of the event persists even after the event has passed and starts interfering with the persons' other activities, it becomes maladaptive. In this study, today's event stress was not associated with tomorrow's worries, which may signal that a maladaptive stress-worry process does not spill over to the next day when taking the effect during the same day into account. Future work that includes information on the intensity or duration of stress reactivity is necessary to determine when adaptive processes become maladaptive.

In this study, we modeled stressfulness of events as an exogenous influence which also enables comparison with previous research on stress-reactivity. Our results are partially consistent with previous findings on stress-reactivity in daily life. Similarly to Bolger and colleagues (1989), we observed little carryover of stressful experiences on mood the next day (<10% of associations between stress and daily symptoms concerned lagged effects). Previous research has suggested that carryover effects may be specific to individuals who are socially isolated or suffer from chronic stress (Caspi et al., 1987). Although we could not investigate these hypotheses in the current dataset, this would be interesting to further explore in future research. In individuals with different types of psychopathology, we found stress-related increases in mild daily expressions of psychopathology that were related to negative affect. This is similar to the type of stress reactivity (i.e., negative affect reactivity) that was observed in individuals with psychotic and mood disorders (Klippel et al., 2018; Myin-Germeys et al., 2003).

However, in contrast to previous studies, we did not observe more stress-reactivity in individuals displaying more psychopathology (Klippel et al., 2018; Wichers et al., 2009). Although we observed that stress was generally associated with higher levels of (mild) daily expressions of psychopathology, these effects were not visible in measures of psychopathology at the epidemiological level, that is, symptom count based on a clinical diagnostic interview that covered the same period as the dairy study. This difference between these findings may be attributable to differences in study design. First, whereas previous research only investigated changes in negative affect in response to stressors, the current study looked at changes in 11 distinct mild, daily expressions of psychopathology. Whether this indicates that only increases in negative affect in response to stress would be a risk factor for psychopathology needs further investigation. Second, we assessed stress and mild expressions of psychopathology once a day, whereas previous studies assessed this multiple times a day. However, this is unlikely to be the sole explanation for not finding an association between stress-reactivity and psychopathology severity, as a recent study with more than 400 hundred adolescents and young adults, which also included multiple assessment each day found no support for this association either. Hence, it may be relevant to further investigate to what extent the size of the daily stressor (Vaessen et al., 2017), the presence of protective factors (e.g., positive appraisal; Hoorelbeke et al., 2019) or the nature of the stressor (e.g., interpersonal conflicts; Bolger et al., 1989) influences the association between stress-reactivity and psychopathology.

One of the promises of modeling person-specific dynamic processes such as stress-reactivity is that between-person differences in the dynamic structure could aid in understanding why, for instance, the impact of stress differs per individual. It has been suggested that such between-person differences may represent

etiological factors or have prognostic value, and could thus elucidate why, for instance, individuals show divergent trajectories after experiencing the same event (Borsboom & Cramer, 2013; Wenzel et al., 2016; Wichers, 2014). Whether this promise (partly) holds depends on the extent to which we are able to quantify which of the many differences in these dynamic processes are meaningful. As in other studies investigating within-person processes (Dotterer et al., 2020; Woods et al., 2020), we found that individuals displayed many different combinations of individual-specific paths (shown in Figure S2). The differences between people in within-person processes were so extensive that we could not investigate whether similarities in within-person processes were associated with similar outcomes. Although this could indicate a need for much larger samples, this finding also highlights a challenge of modeling within-person processes, namely that perhaps, we simply know too little about the optimal ratio between signal (i.e., universal and individual processes) and noise to associate this with meaningful outcomes. A recent commentary by Dejonckheere and colleagues (2020) also stressed the importance of maximizing the signal-to-noise ratio (SNR) in affective time series data. To improve this ratio, more specific questions may be needed (e.g., how did you respond to specific event X?; Dejonckheere et al., 2020). However, this also limits the usability of the data for other questions. For instance, to investigate the effects of stress on psychopathology at the next moment in time, data at the next time point need to reflect individuals' general state of mind and should not be anchored to an event. Thus, the type of data that are collected, the questions that can be answered, and the SNR are closely intertwined.

One of our reasons for using GIMME was that its data-driven subgrouping feature would provide a solution for quantifying similarities in within-person processes for smaller groups of individuals. However, similar to others who used subgrouping GIMME (Dajani et al., 2019; Ellison et al., 2020), we did not observe stable subgroups. Although this might be attributed to the rather heterogeneous nature of our at-risk sample, smaller groups of participants met criteria for the same mini-SCAN diagnosis (e.g., 23 participants with a depressive diagnosis). Simulations showed that under the right conditions (i.e., having at least >90 time points and freely estimated AR effects) subgroup recovery was good to excellent even in much smaller samples (i.e., 25 or 75 individuals) than ours (Lane et al., 2019). This suggests that, if individuals with the same diagnostic label would have exhibited similar symptom dynamics, a stable subgroup would have emerged to reflect this. This could mean two things. First, it might be more complex to find data-driven similarities based on within-person processes in empirical data than simulation studies suggest. Perhaps even when subgroups are present that at first sight seem homogeneous (e.g., having the same diagnosis as was the case in our study), within-person processes itself are much more heterogeneous than anticipated. This requires further study. A second explanation is that (mild) daily expressions of psychopathology and categorical diagnostic approaches capture different aspects of psychopathology. Because this has been largely unexplored, we believe there is a need for more research on how measures of psychopathology at shorter and longer timescales are related.

Strengths of this study include the length of the period of daily assessments (six months) and the large number (n = 122) of participants. Another strength and innovative aspect of our study is that we studied individuals at risk for a wider range of psychopathology domains than is usually done. This allowed investigating whether associations between stress and various mild, daily expressions of psychopathology were cross-diagnostic, which showed that effects on affect rather than behavior manifest across domains and severity levels. Our approach is consistent with the increasing efforts in the broader literature to understand if within-person processes (e.g., stress-reactivity) are different or similar across diagnostic boundaries (Cludius et al., 2020; Insel et al., 2010; Sperry et al., 2021). Moreover, investigating associations between stress and a broader spectrum of specific, mild, daily expressions of psychopathology in the same model acknowledges the complexity of psychopathology and allowed us to observe which effects between stress and these psychopathology domains remained after taking into account associations between the included domains themselves. Last, an important improvement to prior stress-reactivity studies is that we used a method in which we explicitly modeled time-dependencies (instead of mere correlations) between stress and psychopathology domains.

Several methodological considerations should also be kept in mind. First, we used a subjective rather than an objective measure of stress (i.e., self-reported unpleasantness of events). Second, participants responses (both concerning event stress and mild expressions of psychopathology) reflected how they felt on average over the course of the day. Because the majority of associations between stress and psychopathology that we identified were contemporaneous, we cannot draw conclusions on causality. Contemporaneous associations could also represent effects in the opposite direction, reflecting stress generation (e.g., feeling more irritated than normal precedes perceiving negative events as more unpleasant; Hammen, 1991). Furthermore, even though most of the associations surfaced during the same day, this does not imply that X and Y occurred simultaneously. Rather, our once-a-day assessments do not allow us to investigate the directionality of processes occurring within the same day. It is important to keep in mind that contemporaneous associations will also be identified when sampled multiple times a day. In contrast to monitored behaviors (e.g., movement), it is not feasible to collect self-report data using continuous assessment. Third, a key assumption in the current study was that daily diary questions would be able to pick up on daily manifestations of psychopathology. Because our sample consisted of individuals with heightened risk for psychopathology, it was possible that participants experienced increases in mental health problems, decreases, or remained asymptomatic during the study period. A major challenge for daily diary or ecological momentary assessment studies in at-risk samples is therefore to use questions that are both suitable when the intensity of mental health problems is low and when the intensity is high. The diary questions in the current study were therefore designed to also be able to pick up on milder expressions of affect and behavior by (a) inquiring about daily expressions of psychopathological symptoms and (b) reflecting back on the past day rather than asking in one particular moment. A disadvantage of this is that we cannot determine whether responses to these questions are indicative of clinical symptomatology, because this would require using questions on more intense, distressing, or persistent experiences. An advantage, however, is that participants will likely have more variance on the milder expressions which is prerequisite for modeling within-person processes such as stress-reactivity. Finally, because each construct was assessed with a single item, we were not able to calculate reliability estimates (e.g., omega statistic; McDonald, 1999) for the daily diary items.

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Altered stress-reactivity has been proposed as a risk factor for psychopathology. Disentangling individual variation in daily stress-reactivity may aid in understanding differences in outcomes seen after stress exposure. We did not observe that more stress-reactivity is associated with more psychopathology. This study did, however, show that there are general stress-reactivity processes that cross-diagnostic boundaries. In addition, we found many different stress-reactivity patterns across individuals, too many, in fact, to investigate whether similar patterns were also associated with similar outcomes. Thus, the findings of this study speak of the importance of treating stress-reactivity as a dynamic, within-person process that can be different for individuals even when they experience similar psychopathology. Moreover, it also shows the challenges ahead for identifying generalizable processes that reflect mechanisms underlying psychopathology development and persistence.

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