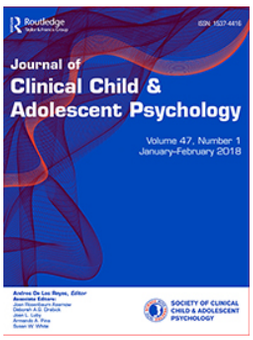

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## SUICIDE AND SELF-INJURY

# Fatigue Moderates the Relationship Between Perceived Stress and Suicidal Ideation: Evidence From Two High-Resolution Studies

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Theoretical models of self-harm suggest that high perceived stress and high fatigue (which might affect the ability to cope with stress) may interact to predict the short-term occurrence of suicidal ideation and nonsuicidal self-injury (NSSI). We tested 3 approaches to examining this interaction, each of which provided a different understanding of the specific nature of these associations: comparing each individual's daily stress/fatigue to the entire sample's overall average (i.e., grand-mean centering), comparing each individual's daily perceived stress/fatigue to his or her overall average (i.e., group- or participant-mean centering), and comparing each individual's average perceived stress/fatigue to the sample's overall average (i.e., centering participant means on overall grand mean). In 2 studies, adolescents ($n = 30$; 574 daily reports, $M$ age = 17.3 years, range = 12–19; 87.6% female) and young adults ($n = 60$; 698 daily reports; $M$ age = 23.25 years, range = 18–35; 85% female) completed daily measures of perceived stress, fatigue, suicidal ideation, and NSSI. In both samples, the interaction between high daily perceived stress and high daily fatigue predicted greater odds of daily suicidal ideation (but not NSSI). Only the model comparing each individual's daily stress/fatigue to the entire sample's overall average was consistently significant across the two studies. Participants were most likely to experience suicidal ideation on days when *both* perceived stress and fatigue were elevated relative to the average level experienced across people and time points. Studies should build upon these findings with more in-depth examination of the temporal nature of stability and change in these factors as they relate to sustained suicidal ideation.

Suicide is a problem of worldwide importance. More than one in 10 adolescents experience serious suicidal ideation by the time they are 18 years old (Nock et al., 2013). Although many risk factors have been identified, recent meta-analytic evidence suggests that they are of limited utility in identifying specifically when an individual will experience suicidal ideation (Franklin et al., 2017; Pigeon, Pinquart, & Conner, 2012). There are at least two reasons for this. First, most informative predictive models include multiple variables that work together to synergistically increase the probability of suicidal behavior when they co-occur (Nock et al., 2008). Despite this, most studies examine additive associations between risk factors and suicide outcomes, rather than in theoretically informed interactive

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combinations. Second, empirical work has shown that suicidal ideation varies considerably from one day to the next (Witte, Fitzpatrick, Warren, Schatschneider, & Schmidt, 2006) with episodes often lasting less than 30 min (Nock, Prinstein, & Sterba, 2009). This means that people who experience suicidal ideation one day may not experience it the next. Despite this understanding, most studies do not utilize methodology that can capture such short-term variation in suicidal ideation. By better understanding these short-term variations, we may be better able to predict (and possibly prevent) days when individuals who are at risk for having suicidal ideation will actually experience suicidal ideation. The primary goal of the present studies was to address these gaps by examining a theoretically relevant combination of risk factors for suicidal ideation—perceived stress and fatigue—using high-resolution within-person methodology (real-time monitoring and daily diary) to capture more fine-grained variation in suicidal ideation than measured in any prior studies.

Several theories of suicide suggest that suicidal thoughts arise in response to a combination of perceptions of intense stress (i.e., one's reaction to a stressor) and a perceived inability to reduce or tolerate this stress, due to either the absence of alternative coping strategies or the perception that alternate coping would be ineffective (Baumeister, 1990; O'Connor, 2011; Shneidman, 1996). According to these theories, perceived stress should be most likely to lead to suicidal ideation when an individual's ability to effectively modulate stress is diminished. Acute fatigue (henceforth, "fatigue"), or temporary difficulty in sustaining effortful cognitive activities brought about by prior prolonged effortful activity (Mizuno et al., 2011), may be one way in which an individual's ability to modulate stress is diminished. Although not explicitly mentioned in most suicide theories, regulatory depletion models suggest that fatigue may be particularly important in diminishing an individual's coping resources (Muraven & Baumeister, 2000). Several studies have found that being fatigued, or even perceiving fatigue (Clarkson, Hirt, Chapman, & Jia, 2011), can lead to deficits in an individual's ability to effectively manage stress and can increase the likelihood that someone will consider risky or dangerous ways to cope (Evans, Boggero, & Segerstrom, 2016; Muraven & Baumeister, 2000). Moreover, experimental sleep deprivation studies have shown that fatigue results in cognitive and emotional impairments that would be expected to interfere with coping processes (Frenda, Berkowitz, Loftus, & Fenn, 2016; Zohar, Tzischinsky, Epstein, & Lavie, 2005).

Both perceived stress (Ang & Huan, 2006; Asarnow, 1992; Cole et al., 2015) and problems with sleep/fatigue (Bernert & Joiner, 2007; Wong & Brower, 2012; Wong, Brower, & Zucker, 2011) have been independently linked to suicide risk, but no study to our knowledge has examined them in tandem. Testing this synergistic effect, over and above main (or additive) effects, is a critical next step for several reasons. First, although perceived stress and fatigue are common occurrences (American Psychological Association, 2014; Eaton et al., 2010), they do not always co-occur, and individuals at risk for suicidal ideation will not experience it every time that they experience stress or fatigue. People may be able to cope with high stress without having suicidal ideation on days when they are not fatigued and cognitive resources are available. In addition, fatigue may not lead to suicidal ideation on days when perceptions of stress are low. Thus, we hypothesized that the combination of perceived stress and fatigue would result in increased probability of experiencing suicidal thoughts. Second, beyond the specific theories just noted, many other theories of suicidal ideation (Joiner, 2005; O'Connor, 2011) propose an interaction of factors as crucial to understanding the occurrence of suicidal ideation. Such interactions, however, are rarely tested (cf. Dour, Cha, & Nock, 2011; Nock et al., 2008).

Nonsuicidal self-injury (NSSI) is related to suicidal thoughts and behaviors in that many individuals who engage in NSSI go on to have suicidal thoughts or engage in suicidal behaviors (Andover, Morris, Wren, & Bruzzese, 2012; Hamza, Stewart, & Willoughby, 2012). Given the link between NSSI and suicidal thoughts, we were interested in whether the proposed model would generalize from the prediction of suicidal ideation to the prediction of NSSI, or whether it is specific to suicidal ideation. Although we had no a priori hypotheses, we reasoned that our model could generalize to NSSI (i.e., synergistic effects of perceived stress and fatigue may apply to both suicidal ideation and NSSI) or be specific to suicidal ideation (i.e., synergistic effects apply to suicidal ideation but not NSSI). In terms of generalizability, perceived stress (Dickey, Reisner, & Juntunen, 2015; Fliege et al., 2006; Kiekens et al., 2015) and factors relating to fatigue (e.g., poor sleep; Lundh, Bjärehed, & Wångby-Lundh, 2013) have been associated with risk for NSSI. Their synergistic combination, however, has not yet been assessed. This is especially relevant because NSSI can be conceptualized as a maladaptive coping strategy (Borrill, Fox, Flynn, & Roger, 2009; Cawood & Huprich, 2011) or maladaptive way to regulative emotions (Nock, 2010). It may be that adolescents are more likely to engage in fewer adaptive coping strategies like NSSI when they are feeling especially stressed and too fatigued to engage in a more adaptive method of coping. Moreover, there is some preliminary evidence for the idea that compared to adolescent suicide attempters, adolescents who engage in NSSI perceive higher levels of stress during stress-inducing experimental paradigms (i.e., the Prisoner's Dilemma task in one study; Kim et al., 2015). In support of specificity, there has been a push to find factors that

distinguish self-injurious thoughts from self-injurious behaviors. Although many previous studies have focused on the differences between suicidal ideation and attempts (Nock et al., 2008; Nock, Kessler, & Franklin, 2016), there also is a strong need to identify factors that distinguish between suicidal ideation and NSSI.

## Perceived Stress, Fatigue, Suicidal Ideation, and NSSI Across the Life Span

Some researchers have suggested that the effects of stressors on psychological functioning may be especially pronounced during childhood and adolescence (Romeo, 2013), whereas others propose that the effects of stress impact the risk of psychological and behavioral problems throughout the course of development (Lupien, McEwen, Gunnar, & Heim, 2009). For instance, perceptions of stress have been linked with the risk of suicidal ideation across both adolescent (Abdollahi, Carlbring, Khanbani, & Ghahfarokhi, 2016; Buitron et al., 2016; De Man, 1999) and adult (Cole et al., 2015; Feng, Li, & Chen, 2015) samples. Similarly, a recent meta-analysis showed no moderating effect of age on the association between stressful life events and risk of NSSI (R. Liu, Cheek, & Nestor, 2016).

Fatigue is an especially common occurrence among adolescents, nearly 30% of whom report experiencing it regularly (Findlay, 2008), suggesting that the negative effects of fatigue might be more common among adolescents. Other research suggests that the propensity to experience fatigue begins in early adolescence and is consistent throughout young adulthood (Ter Wolbeek, Van Doornen, Kavelaars, Tersteeg-Kamperman, & Heijnen, 2011). Similar to perceived stress, there is work that demonstrates a consistent link across the life span between fatigue (and related factors e.g., sleep quality) and suicidal ideation (Pigeon et al., 2012) and between fatigue and NSSI (Hochard, Heym, & Townsend, 2015; X. Liu, Chen, Bo, Fan, & Jia, 2016; Lundh et al., 2013).

To summarize, there is research suggesting that the associations between perceived stress, fatigue, and suicidal ideation/NSSI may either be more pronounced during adolescence or exist consistently across different developmental stages. Although more evidence points to the latter rather than the former, it is still important to clarify the specific developmental nature of the relationship between stress, fatigue, and suicidal ideation/NSSI. Accordingly, in the current study we examined these associations in both adolescent and adult samples.

## Methodological Concerns in the Study of Stress, Fatigue, NSSI, and Suicidal Ideation

To most effectively study the interaction between perceived stress and fatigue, microlongitudinal methods that assess within-person day-to-day variations in fatigue, perceived stress, and suicidal ideation/NSSI are required. Fatigue, perceived stress, suicidal ideation, and NSSI vary considerably from day to day, and their effects are generally most relevant during a short period (i.e., same day or next day, but usually not beyond this period; Adam, Snell, & Pendry, 2007; Gunthert, Cohen, Butler, & Beck, 2007; Witte et al., 2006). Surprisingly, however, most longitudinal studies of self-injurious thoughts and behavior have used only a few assessment points separated by several months or longer (Khurana & Romer, 2012; Wong & Brower, 2012). The two studies reported here used microlongitudinal methods that had many assessment points separated by only a day. Study 1 used interval-contingent (i.e., daily diary) and event-contingent ecological momentary assessment, and Study 2 used daily diaries. Both methods allowed us to capture important within-person variation in perceived stress, fatigue, and probability of experiencing suicidal thoughts.

Microlongitudinal methods provide opportunities to study within-person associations between constructs that are not typically available in less time-intensive methods. However, these methods also pose unique challenges for data analysis. One such challenge is that data are typically centered on a relevant comparison point prior to analysis to facilitate interpretability of the resulting coefficients. Several centering methods are available for within-person data, and the decision of which to use is central to conducting analyses (Aiken & West, 1991; Enders & Tofighi, 2007). There are no strong empirical guidelines for choosing between centering methods, and it has been suggested that the best method is one that has potential to provide an understanding of the data that are compatible with the theory being tested (Hofmann & Gavin, 1998). Accordingly, we compared three theoretically compatible centering methods:

1. *Grand-mean centering* compares each participant's daily perceived stress or fatigue to the entire sample's overall average perceived stress or fatigue across time points. This assumes that perceived stress and fatigue are most relevant in terms of their position relative to the overall average level of perceived stress for the typical participant. This model is consistent with theoretical models suggesting that stress and fatigue act as relatively consistent risk factors for suicidal ideation and that once a threshold is reached in any given moment, people will become increasingly likely to respond with suicidal ideation (Rudd, 1990). Because each participant's score is centered on the entire sample average, whether someone is considered at high risk depends on who else is in the sample. The formula for grand-mean centering can be described as (Participant daily score)—(Overall sample average score).

2. *Participant-mean centering (i.e., group mean centering)* compares each participant's daily level of perceived stress or fatigue to that individual participant's overall average perceived stress or fatigue across time, thus removing

any between-person variation. This assumes that perceived stress and fatigue are most relevant in terms of their position relative to each participant's typical level of perceived stress. This model is consistent with theories suggesting that an individual is most likely to consider suicide at his or her own "high water mark," relative to his or her own baseline regardless of how this level compares to others (Bryan & Rudd, 2016). The formula for participant-mean centering can be described as (Participant daily score)—(Participant average score).

3. *Centering participant means on the grand mean* compares an individual's average level of perceived stress or fatigue across the study period to the entire sample's average level of stress or fatigue across the study period. This assumes that stress and fatigue are most relevant in terms of a participant's overall average relative to all other participants' overall average. This model is consistent with a conceptualization that people who experience chronically elevated perceptions of stress and fatigue, relative to the average level experienced by others, are most vulnerable to experiencing negative outcomes. The formula for centering individual participant means on the grand mean can be described as (Participant average score)—(Sample average score).

In summary, because neither theory nor existing research provided strong guidance on which method of centering should be preferred, we examined three centering methods: comparing each individual's daily perceived stress/fatigue to the entire sample's overall average (i.e., grand-mean centering), comparing each individual's daily perceived stress/fatigue to that individual's overall average (i.e., participant-mean centering), and comparing each individual's overall average stress/fatigue to the entire sample's overall average (i.e., centering participant means on overall grand means). Using three methods of centering is important because it helps to clarify the nature of how perceived stress and fatigue operate to confer risk for suicidal ideation and NSSI. A grand-mean centered model suggests that perceived stress and fatigue are daily-level processes. A participant-mean centered model also suggests that stress and fatigue are daily-level processes but adds the implication that the risk is conferred by elevations in perceived stress and fatigue relative to an individual's average. Finally, a participant-mean centered on grand-mean model suggests that perceived stress and fatigue are stable processes that confer risk over a period longer than a day.

## The Current Studies

Across two studies, we tested the hypotheses that perceived stress and fatigue interact to predict greater likelihood of experiencing (a) suicidal ideation and (b) NSSI than either factor alone. The first study included a sample of adolescents from a group at high risk for suicidal thoughts (i.e., those who engaged in NSSI; Hamza et al., 2012) and used interval-contingent (i.e., daily diary) and event-contingent (i.e., reporting in or near the moment when suicidal ideation or NSSI occurred) ecological momentary assessment to assess self-injurious thoughts and behaviors as they occurred throughout the day. The second study included a sample of young adults and used a daily diary design to examine daily perceptions of stress, fatigue, and suicidal ideation. Using within-person assessments allowed us to measure perceived stress, fatigue, suicidal ideation, and NSSI on the day they occurred rather than over much larger and less accurate time frames. The examination of a synergistic model allowed us to challenge the assumption made by bivariate-effect only studies, namely, that the same level of fatigue or perceived stress would lead to the same level of suicidal ideation across all people and all days.

# STUDY 1

## Method

### Participants

Participants were 30 adolescents ($M$ = 17.3 years, $SD$ = 1.9, range = 12–19; 86.7% female, 86.7% European American) recruited from a larger study on self-injury (see Nock & Mendes, 2008). The major inclusion criterion was engaging in NSSI in the past 2 weeks.

### Procedure

Over a 14-day period, participants were asked to complete study items on a Palm Pilot device every time they thought about suicide or engaged in NSSI (i.e., event-contingent monitoring) and were prompted before bedtime to complete daily diary logs regarding perceived stress and fatigue, among other factors. Participants were compensated through keeping the Palm Pilot or returning it to the lab for $100. Participants reported on a total of 574 days, averaging 19.1 days each ($SD$ = 7.20 days, range = 1–33 days). Nearly all (90%) of the participants completed at least 10 days of data collection, and most (83%) completed at least 13 days of data collection (i.e., they only missed 1 of 14 days). Several individuals could not return the Palm Pilot immediately after the 14-day period ended and continued to record data. Further information on participants and data collection is available elsewhere (Nock et al., 2009).

### Measures

*Perceived stress.* At each bedtime assessment, participants were asked how much stress they perceived during

the day from the following seven sources: parents, sibling/family, school/work, athletics/recreation, peers, teacher/boss, and dating/romantic relationships. The question was presented such that a screen with the text "How high was stress from …" was displayed at the top with the relevant stem (e.g., parents) next to it, along with a 5-point scale ranging from 0 (*not present*) to 4 (*very severe*). We averaged the score across all six domains to create a composite stress score.

*Fatigue.* At each bedtime assessment, participants were asked to rate their level of fatigue over the past day. The question was presented such that a screen with the text "How tired /energetic today?" was displayed at the top along with a 7-point scale ranging from 0 (*very energetic*) to 6 (*very tired*).

*Suicidal ideation and NSSI.* Participants were asked to initiate a log whenever they experienced a suicidal thought or engaged in NSSI during the day. They were also able to report during the bedtime log any episodes of suicidal ideation or NSSI that were not previously reported. Participants were presented with an item that said, "Did you think of doing any of the following?" (previous screens had set the context for whether it was an event-contingent prompt or whether it was a bedtime prompt asking about any missed responses) along with choices for "direct self-harm" and "attempt suicide." If "attempt suicide" was noted, we considered this evidence of presence of suicidal ideation. If "direct self-harm" was noted, participants were asked, "Did you self-injure?" and if participants endorsed this, we considered it evidence of NSSI. Prior to beginning the study, participants were given the following definitions of NSSI ("Direct self-harm is harming yourself without wanting to die") and attempting suicide ("Attempted suicide is harming yourself with the intention of dying"). Because suicidal thoughts or NSSI could be recorded at any point during the day or during the bedtime log, we created variables that indicated presence (1) or absence (0) of suicidal thoughts at any point in the day and NSSI at any point in the day.

### Analytic Strategy

Before conducting the main analyses, we estimated the reliability of any scales that included multiple items (i.e., perceived stress in both studies as no other measures were multiple-item scales) according to Nezlek's (2016) recommendations. This involved creating unconditional models with an added "item" level that contained the component items used to create a composite scale. That is, individual component items (Level 1) were nested within days (Level 2) within people (Level 3). The item level's intercept ($\lambda$) can be interpreted in a similar way to Cronbach's alpha. This interpretation should be done, however, "at more relaxed standards" (Nezlek, 2016) because many statelike factors that are well suited for daily diary studies fluctuate frequently and because the sources of stress are discrete and may not map onto one unitary construct.

As previously discussed, the choice of centering method has important implications for the interpretation of results from microlongitudinal data analysis (Aiken & West, 1991; Enders & Tofighi, 2007). The following methods were directly compared in our analyses: (a) A grand-mean centered model, which involved subtracting the overall sample mean across participants and days from each individual response. This results in an intercept that can be interpreted as the expected value of the dependent variable for an individual who scores at the mean level of the independent variable, considering the whole sample. (b) A participant-mean centered model, which involved subtracting each participant's overall mean across days from each of their daily responses. This results in an intercept that is interpreted as the expected value for the dependent variable when the independent variable is at that individual's mean. (c) A combination model, which involved subtracting the overall sample grand-mean from each participant's mean, creating a Level 2 (i.e., between-person) variable. This results in an intercept that is interpreted as the expected value for the dependent variable when the independent variable at that individual's mean, considering the whole sample's mean.

For each outcome variable (i.e., suicidal ideation and NSSI) we conducted three moderated multilevel regression models that differed in how we centered the predictors. The grand-mean and participant-mean centered analyses had all variables assessed at Level 1 (i.e., within-person level). The participant-mean centered on grand-mean analyses had the predictors (i.e., perceived stress, fatigue, and the interaction between the two) at Level 2. Because suicidal ideation and NSSI were binary variables (yes/no), we used multilevel logistic regression. Analyses were conducted in R (R Core Team, 2016) using the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015). Tables and figures were created with the *sjPlot* package (Lüdecke, 2016). Significant interactions were probed using the tool provided by Preacher, Curran, and Bauer (2006).

## RESULTS AND DISCUSSION

Twenty-six days of suicidal ideation were reported by 10 participants (range = 1–5 days per participant reporting ≥ 1 day of suicidal ideation). Twenty-two of the 26 reports of suicidal ideation (84.6%) were noted during the user-initiated event-contingent reports, and the remaining four were noted at the end-of-day prompt asking if there were any unreported instances of suicidal ideation. A total of 76 days of NSSI were reported by 23 participants (range = 1–10 days per participant reporting at least one day of NSSI). Sixty-nine of the 76 reports of NSSI (90.8%) were noted during the user-initiated event-contingent reports, and the

TABLE 1
Correlations and Descriptive Statistics for Study 1 Variables

| | *Within-Person Correlations* | | | *Between-Person Correlations* | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Variable* | *1* | *2* | *3* | *1* | *2* | *3* | *(Grand)* M | SD | ICC |
| 1. Fatigue | — | | | — | | | 3.37 | 1.59 | .15 |
| 2. Stress | .29*** | — | | .41* | — | | 6.80 | 4.72 | .62 |
| 3. Suicidal Ideation | .01 | .04 | — | .06 | .28 | — | — | — | .12 |
| 4. NSSI | .05 | .12** | .01 | .09 | .25 | −.18 | — | — | .10 |

*Note*. ICC = intraclass correlation; NSSI = nonsuicidal self-injury.
*$p < .05$. **$p < .01$. *** $p < .001$.

remaining seven were noted at the end-of-day prompt asking if there were any unreported instances of NSSI. The reliability of the stress ratings was fair for statelike measures ($\lambda = .275$). Bivariate correlations, intraclass correlations (ICCs), and descriptive statistics are reported in Table 1.

The results of the models testing the interaction between perceived stress and fatigue predicting suicidal ideation are shown in Table 2. The model centering on the grand-mean (i.e., examining participant's daily scores to those of all participants across all days) provided the best fit to the data, as evidenced by the lowest Akaike information criterion and deviance. The interaction of perceived stress and fatigue was also significant in models using participant-means centered on grand means (i.e., comparing the participants' scores from all days to those of all participants across all days). There were no significant effects in the model using participant-mean centering (i.e., comparing participants' daily scores to *their own* mean calculated using data from all days). Further examination of the significant interaction from the model using grand-mean centering (Figure 1) showed that the association between perceived stress and the odds of suicidal ideation was stronger on high fatigue days (+1 *SD;* $b = 0.88$, $z = 8.26$, $p < .001$) than it was on average ($b = 0.34$, $z = 4.56$, $p < .001$) or low fatigue days (−1 *SD;* $b = -0.22$, $z = -1.93$, $p = .054$). Further examination of the significant interaction from the model using participant-means centered on grand-means (Figure 2) showed that the positive relationship between perceived stress and the odds of suicidal ideation was stronger for those who had higher than average levels of fatigue (+1 *SD;* $b = 0.43$, $z = 2.65$, $p = .008$) than it was for those who had average ($b = 0.22$, $z = 1.85$, $p = .065$) or lower than average (−1 *SD;* $b = 0.005$, $z = 0.35$, $p = .972$) levels of fatigue.

The analyses testing the interaction between perceived stress and fatigue predicting NSSI are shown in Table 3. The main effect for stress was significant in the models using grand-mean and participant-mean centering. No other main effects or interactions were significant.

The results of the analysis for Study 1 supported our main hypothesis regarding suicidal ideation but not NSSI. High perceived stress and high fatigue interacted to predict

TABLE 2
Results of Regression Analysis Predicting Daily Suicidal Ideation (Study 1)

| | *Grand-Mean Centering* | | | | *Participant-Mean Centering* | | | | *Participant Mean on Grand Mean* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OR | CI | SE | p | OR | CI | SE | p | OR | CI | SE | p |
| Fixed Parts | | | | | | | | | | | | |
| (Intercept) | 0.02 | [0.00, 0.08] | 0.70 | < .001 | 0.02 | [0.00, 0.07] | 0.75 | < .001 | 0.02 | [0.00, 0.07] | 0.68 | < .001 |
| Stress | 1.40 | [0.75, 2.63] | 0.32 | .290 | 1.03 | [0.88, 1.19] | 0.08 | .737 | 1.25 | [0.99, 1.58] | 0.12 | .065 |
| Fatigue | 0.99 | [0.73, 1.36] | 0.16 | .980 | 1.02 | [0.73, 1.43] | 0.17 | .902 | 0.84 | [0.57, 1.22] | 0.19 | .359 |
| Stress × Fatigue | 1.41 | [1.03, 1.94] | 0.04 | .034 | 0.97 | [0.88, 1.06] | 0.05 | .485 | 1.15 | [1.03, 1.28] | 0.05 | .012 |
| Random Parts | | | | | | | | | | | | |
| $\tau_{00,\ Participant}$ | | 3.072 | | | | 3.659 | | | | 2.567 | | |
| $N_{Participant}$ | | 30 | | | | 29[a] | | | | 29[a] | | |
| $ICC_{Participant}$ | | 0.483 | | | | 0.527 | | | | 0.438 | | |
| Observations | | 479 | | | | 478 | | | | 478 | | |
| AIC | | 190.40 | | | | 192.21 | | | | 183.69 | | |
| Deviance | | 141.50 | | | | 141.04 | | | | 137.81 | | |

*Note*. OR = odds ratio; CI = confidence interval; ICC = intraclass correlation; AIC = Akaike information criterion.
[a]One participant had only one day of data and was thus excluded from analyses that used group means.

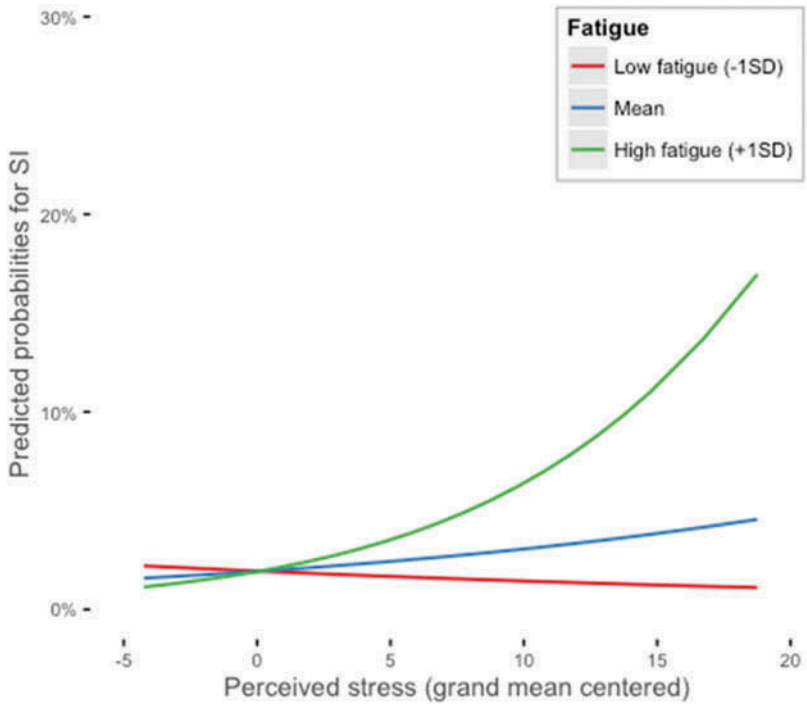


FIGURE 1 Fatigue as a moderator of the relationship between perceived daily stress and odds of daily suicidal ideation (SI) using grand mean centering (Study 1).

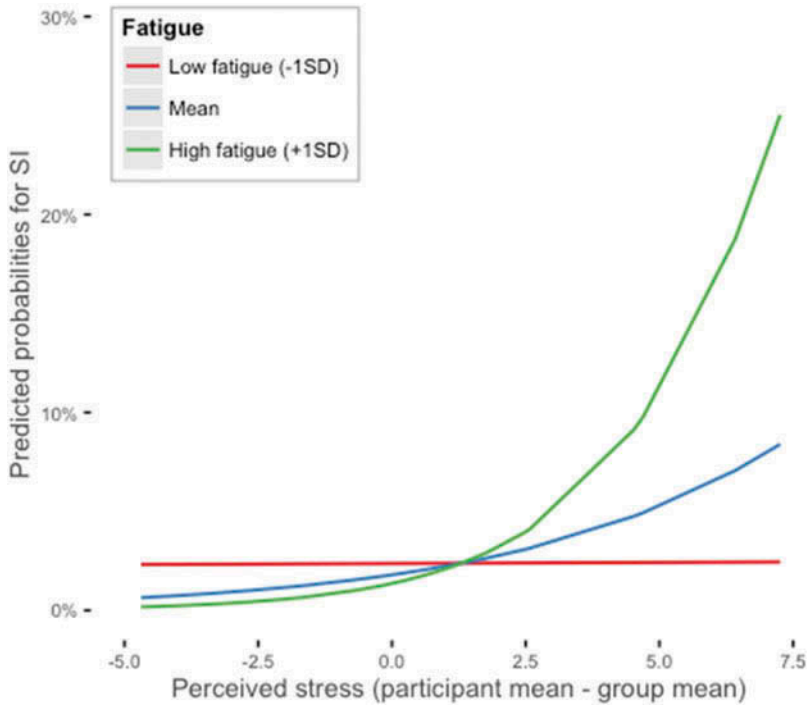


FIGURE 2 Fatigue as a moderator of the relationship between perceived daily stress and odds of daily suicidal ideation (SI) using participant mean minus grand mean centering (Study 1).

TABLE 3
Results of Regression Analysis Predicting Daily Nonsuicidal Self-Injury (Study 1)

| | *Grand-Mean Centering* | | | | *Participant-Mean Centering* | | | | *Group Mean on Grand Mean* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OR | CI | SE | p | OR | CI | SE | p | OR | CI | SE | p |
| Fixed Parts | | | | | | | | | | | | |
| (Intercept) | 0.14 | [0.09, 0.23] | 0.25 | < .001 | 0.14 | [0.09, 0.22] | 0.24 | < .001 | 0.14 | [0.09, 0.23] | 0.24 | < .001 |
| Stress | 1.11 | [1.02, 1.20] | 0.04 | .013 | 1.13 | [1.03, 1.25] | 0.05 | .011 | 1.12 | [0.99, 1.27] | 0.06 | .066 |
| Fatigue | 0.92 | [0.76, 1.11] | 0.10 | .396 | 0.92 | [0.76, 1.12] | 0.10 | .404 | 0.89 | [0.74, 1.06] | 0.09 | .194 |
| Stress × Fatigue | 1.03 | [0.99, 1.07] | 0.02 | .139 | 1.03 | [0.96, 1.10] | 0.03 | .428 | 1.03 | [0.98, 1.09] | 0.03 | .294 |
| Random Parts | | | | | | | | | | | | |
| $\tau_{00,\ Participant}$ | | 0.850 | | | | 0.854 | | | | 0.797 | | |
| $N_{Participant}$ | | 30 | | | | 29[a] | | | | 29[a] | | |
| $ICC_{Participant}$ | | 0.205 | | | | 0.206 | | | | 0.195 | | |
| Observations | | 479 | | | | 478 | | | | 478 | | |
| AIC | | 403.44 | | | | 402.87 | | | | 405.97 | | |
| Deviance | | 350.75 | | | | 349.94 | | | | 354.64 | | |

*Note*. OR = odds ratio; CI = confidence interval; ICC = intraclass correlation; AIC = Akaike information criterion.
[a]One participant had only one day of data and was thus excluded from analyses that used group means.

increased likelihood of suicidal ideation in models using grand-mean and participant-mean centering on grand-mean centering but not participant-mean centering. This suggests that risk of suicidal ideation is greatest when stress and fatigue for an individual are high relative to the average level experienced across individuals (i.e., when a person is much more stressed than everyone else). Within-person variations from individual averages do not capture the synergistic risk conferred by perceived stress and fatigue when they co-occur.

This study had several strengths such as the use of high-resolution data collection in a high-risk sample. However, we tested three interactional models with two outcomes, raising the possibility that the results may reflect a Type I error. To test the replicability of these findings and to examine whether a similar association exists later in the course of development, we sought to replicate these results in a sample of adults using similar study design, assessment methods, and data analyses.

## STUDY 2

### Method

#### *Participants*

Participants were 60 young adults ($M$ = 23.25 years, $SD$ = 4.25, range = 18–35; 53.3% White; 85% female) recruited from a larger study of self-injury (see Turner, Cobb, Gratz, & Chapman, 2016). The major inclusion criteria were 10 or more lifetime episodes of NSSI, one or more NSSI episodes in the past year, and NSSI thoughts or urges within the past 2 weeks.

#### *Procedure*

Participants logged in to a secure online survey each night during a 14-day diary period. Three participants completed an extra day, resulting in a maximum of 15 entries. Compliance was good, with a mean of 12.25 entries ($SD$ = 3.20) per participant and the majority of the sample (86.6%) completing 10 or more entries. Using a day reconstruction method (Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004), participants retrospectively reported on their perceived stress and energy levels during the morning (defined as waking until noon), afternoon (defined as noon to 6 p.m.), and evening (defined as 6 p.m. until the diary entry). Participants were then asked if they had experienced any thoughts about suicide or engaged in NSSI at any time during the day. Eight participants who missed entries were given an option to continue to record data beyond the 14 days, with a maximum total monitoring period of 17 days. Participants received up to $120 for their participation.

#### *Measures*

*Perceived stress.* Participants rated their perceived stress during the morning, afternoon, and evening using the 10-item Perceived Stress Scale (Cohen, Kamarck, & Mermelstein, 1983). Items are rated on a 0 (*never*) to 4 (*very often*) scale. Sum scores for each period were used, creating three perceived stress scores for morning, afternoon, and evening. The Perceived Stress Scale is a particularly good measure for our purposes because given the conceptual overlap between perceived stress and depression and between depression and suicidal ideation and NSSI, it is important to use a measure of perceived stress that does not

conflate perceived stress with depressive symptoms. The Perceived Stress Scale still predicts negative outcomes like physical health functioning while partialling out the variance contributed by measures of depression symptoms (Cohen et al., 1983).

*Fatigue.* Participants rated their energy level during the morning, afternoon, and evening on a 0 (*very awake*) to 6 (*very tired*) scale using a single item from the Multidimensional Mood Questionnaire (Wilhelm & Schoebi, 2007). For example, participants were asked, "This afternoon, did you feel very tired … very awake?" with six radio buttons indicating relative position on the bipolar scale from which to choose. Individual scores from each period were used.

*Suicidal ideation and NSSI.* Suicidal ideation was assessed with a single, dichotomous (yes/no) item: "Did you think of doing the following today (even if it was only a passing thought)—attempting suicide?" NSSI was assessed with a single item: "Did you engage in nonsuicidal self-injury" (defined in a previous item as "injuring yourself without intending to die").

### Analytic Strategy

We tested our hypothesis using the same general method as Study 1. The only difference was that because ratings of perceived stress were given once per day for three periods during each day, we utilized a three-level model where periods (i.e., morning, afternoon, and evening) were nested within days, which were nested within people. This allowed us to create interaction terms between the perceived stress and fatigue scores from each period. As in the previous study, because they were assessed on a daily basis (e.g., "Did you have suicidal thoughts at all today?"), suicidal ideation and NSSI were at the within-person level (i.e., Level 2, as there were three levels).

## RESULTS AND DISCUSSION

Participants reported over 698 days, averaging 12.25 days each ($SD$ = 3.20 days). A total of 90 days of suicidal ideation were reported by 31 participants (range = 1–9 days per participant), and a total of 90 days of NSSI were reported by 34 participants (range = 1–12 days per participant). The reliability of the Perceived Stress Scale was fair for statelike measures ($\lambda = .279$). Bivariate correlations, ICCs, and descriptive statistics are reported in Table 4.

The main effects for perceived stress and the interaction between perceived stress and fatigue significantly predicted suicidal ideation in the grand-mean centered model only (see Table 5 and Figure 3). As in Study 1, the relationship between perceived stress and the odds of suicidal ideation was stronger on high fatigue (+1 *SD;* $b = 0.17$, $z = 6.13$, $p < .001$) days than it was on average ($b = 0.12$, $z = 8.24$, $p < .001$) or low fatigue (−1 *SD;* $b = 0.01$, $z = 2.27$, $p = .002$) days. The proposed interaction was no longer significant when using participant mean-centering, and once again was not significant centering participant mean on the grand-mean. The analyses testing the interaction between fatigue and perceived stress predicting NSSI are shown in Table 6. As in Study 1, the main effect for perceived stress was significant in the models using grand-mean and participant-mean centering. No other effects were significant.

The goal of Study 2 was to conceptually replicate Study 1's findings in a sample of adults. Studies 1 and 2 differed in a few key ways that limited their exact overlap. First, they measured perceived stress and fatigue at different frequencies. Study 1 measured perceived stress and fatigue once per day, whereas Study 2 measured perceived stress and fatigue once per day but referenced three discrete periods during each assessment (i.e., perceived stress during the morning, afternoon, and night was assessed discretely during a single assessment at the end of the night). Second, they used

TABLE 4
Correlations and Descriptive Statistics for Study 2 Variables

| | *Within-Person Correlations* | | | *Between-Person Correlations* | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| *Variable* | *1* | *2* | *3* | *1* | *2* | *3* | *(Grand)* M | SD | ICC |
| 1. Fatigue | — | | | — | | | 10.72 | 3.98 | .42 |
| 2. Perceived Stress | .30*** | — | | .50*** | — | | 51.90 | 21.10 | .57 |
| 3. Suicidal Ideation | .26*** | .21*** | — | .31* | .35** | — | — | — | .17 |
| 4. NSSI | .07 | .23*** | .15* | −.10 | −.16 | −.06 | — | — | .26 |

*Note*. ICC = intraclass correlation; NSSI = nonsuicidal self-injury.
*$p < .05$. **$p < .01$. ***$p < .001$.

TABLE 5
Results of Regression Analysis Predicting Daily Suicidal Ideation (Study 2)

| | *Grand-Mean Centering* | | | | *Participant-Mean Centering* | | | | *Group Mean on Grand Mean* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | OR | CI | SE | p | OR | CI | SE | p | OR | CI | SE | p |
| Fixed Parts | | | | | | | | | | | | |
| (Intercept) | 0.02 | [0.01, 0.05] | 0.46 | < .001 | 0.02 | [0.01, 0.06] | 0.48 | < .001 | 0.34 | [0.00, 38.86] | 2.42 | .656 |
| Perceived Stress | 1.13 | [1.09, 1.16] | 0.01 | < .001 | 1.13 | [1.10, 1.16] | 0.01 | < .001 | 0.89 | [0.66, 1.21] | 0.15 | .466 |
| Fatigue | 1.02 | [0.91, 1.14] | 0.06 | .744 | 1.04 | [0.93, 1.16] | 0.06 | .533 | 0.75 | [0.18, 3.11] | 0.72 | .696 |
| Stress × Fatigue | 1.01 | [1.00, 1.03] | 0.01 | .033 | 1.00 | [0.99, 1.02] | 0.01 | .885 | 1.02 | [0.94, 1.11] | 0.04 | .622 |
| Random Parts | | | | | | | | | | | | |
| $\tau_{00,\ Participant}$ | | 5.161 | | | | 6.013 | | | | 2.205 | | |
| $\tau_{00,\ Day}$ | | 0.476 | | | | 0.474 | | | | — | | |
| $N_{Participant}$ | | 60 | | | | 60 | | | | 60 | | |
| $N_{Day}$ | | 17 | | | | 17 | | | | — | | |
| $ICC_{Participant}$ | | 0.578 | | | | 0.615 | | | | 0.401 | | |
| $ICC_{Day}$ | | 0.053 | | | | 0.048 | | | | — | | |
| Observations | | 2180 | | | | 2180 | | | | 732 | | |
| AIC | | 1185.80 | | | | 1195.51 | | | | 477.53 | | |
| Deviance | | 979.20 | | | | 982.80 | | | | 373.80 | | |

*Note*. OR = odds ratio; CI = confidence interval; ICC = intraclass correlation; AIC = Akaike information criterion.

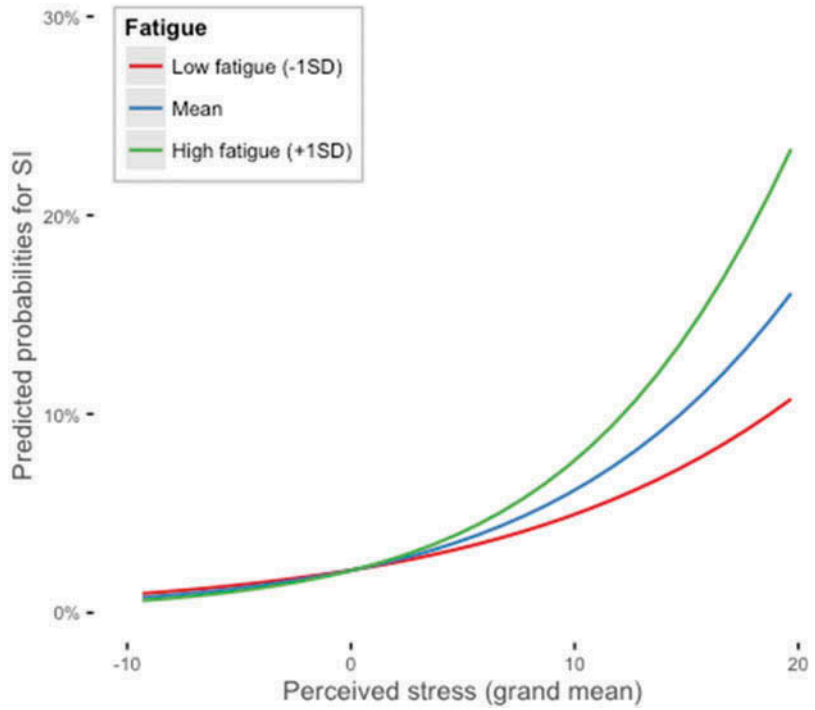


FIGURE 3 Fatigue as a moderator of the relationship between perceived daily stress and odds of daily suicidal ideation (SI) using grand mean centering (Study 2).

different age groups. Study 1 used a sample of adolescents, whereas Study 2 used a sample of young adults. Beyond the importance of replication, using a sample of adults allowed us to show whether perceived stress and fatigue synergistically predict suicidal ideation and NSSI across different age groups.

The results from Study 2 partially supported our hypothesis. The interaction between perceived stress and fatigue synergistically predicted greater odds of suicidal ideation when perceived stress and fatigue are elevated relative to the average level experienced across people and time points. The interaction between perceived stress

TABLE 6
Results of Regression Analysis Predicting Daily Nonsuicidal Self-Injury (Study 2)

| | *Grand-Mean Centering* | | | | *Participant-Mean Centering* | | | | *Group Mean on Grand Mean* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | *OR* | *CI* | *SE* | p | *OR* | *CI* | *SE* | p | *OR* | *CI* | *SE* | p |
| Fixed Parts | | | | | | | | | | | | |
| (Intercept) | 0.03 | [0.01, 0.06] | 0.43 | < .001 | 0.03 | [0.01, 0.07] | 0.41 | < .001 | 0.34 | [0.00, 38.86] | 2.42 | .656 |
| Stress | 1.10 | [1.07, 1.13] | 0.01 | < .001 | 1.10 | [1.07, 1.13] | 0.01 | < .001 | 0.89 | [0.66, 1.21] | 0.15 | .466 |
| Fatigue | 1.04 | [0.94, 1.15] | 0.05 | .464 | 1.04 | [0.94, 1.15] | 0.05 | .477 | 0.75 | [0.18, 3.11] | 0.72 | .696 |
| Stress × Fatigue | 1.00 | [0.99, 1.01] | 0.01 | .849 | 1.00 | [0.99, 1.02] | 0.01 | .945 | 1.02 | [0.94, 1.11] | 0.04 | .622 |
| Random Parts | | | | | | | | | | | | |
| $\tau_{00,\ Participant}$ | | 6.114 | | | | 5.246 | | | | 2.205 | | |
| $\tau_{00,\ Day}$ | | 0.172 | | | | 0.170 | | | | — | | |
| $N_{Participant}$ | | 60 | | | | 60 | | | | 60 | | |
| $N_{Day}$ | | 17 | | | | 17 | | | | — | | |
| $ICC_{Participant}$ | | 0.639 | | | | 0.603 | | | | 0.401 | | |
| $ICC_{Day}$ | | 0.018 | | | | 0.020 | | | | — | | |
| Observations | | 2181 | | | | 2181 | | | | 732 | | |
| AIC | | 1168.43 | | | | 1164.35 | | | | 477.53 | | |
| Deviance | | 962.34 | | | | 964.13 | | | | 373.80 | | |

*Note*. OR = odds ratio; CI = confidence interval; ICC = intraclass correlation; AIC = Akaike information criterion.

and fatigue did not synergistically predict greater odds of suicidal ideation when levels of perceived stress and fatigue are considered relative to each person's own average level, or when the individual's average level across time relative to the sample's average across time. The replication of this pattern of results in an independent sample strengthens our confidence in the robustness and external validity of these results.

## GENERAL DISCUSSION

We tested whether perceived stress and fatigue interact to predict the daily occurrence of suicidal thoughts and NSSI among those at risk for these outcomes. The two studies reported here yielded two important and consistent findings. First, days marked by high levels of perceived stress and fatigue, relative to the average level of perceived stress and fatigue experienced across all participants and periods, were associated with significantly increased odds of suicidal ideation. In contrast, when levels of perceived stress and fatigue were considered relative to each individual's own personal average, the interaction was not significant. These results suggest that between-person differences, rather than within-person daily changes, are most important for predicting occurrences of suicidal ideation. Second, this synergistic relationship between high levels of perceived stress and fatigue appears to be specific to suicidal ideation; a similar pattern was not identified when predicting daily acts of NSSI. Instead, both studies revealed that risk for engaging in NSSI was greatest on high stress days, regardless of the level of fatigue relative to an individual's own mean or relative to the mean across participants. Each of these findings warrants additional comment.

Our primary hypothesis was that the interaction of high perceived stress and high fatigue would predict, beyond the main effect of either of these risk factors alone, the experience of suicidal ideation on a given day. Both studies supported this hypothesis—but only when a person's daily stress is elevated related to the average amount of stress experienced by others. Notably, the grand-mean centering approach used here is sample-specific, and whether someone is considered at high risk depends on who else is in the sample. This means that in the present studies, high versus low perceived stress and fatigue were determined relative to the sample of individuals who recently engaged in NSSI. Accordingly, without further replication, the generalizability of these findings is limited to the population of individuals who engage in NSSI.

Both studies also provided consistent evidence that perceived stress and fatigue, when centered on the participant mean, did *not* predict greater odds of suicidal ideation. One explanation might be that although the effects of stress on factors like suicidal ideation are most relevant during the same day, a stressful day does not usually occur in isolation and stress stemming from an event (e.g., a fight with a significant other) tends to spill over from one day to the next or to longer periods. For example, if an adolescent has a fight with a significant other today, the situation is likely not resolved tomorrow or even a few days later. Because the study periods were relatively short, we may have been able to capture stressful periods of a few days or longer but were unable to capture participant's true baseline level of stress, which may have been apparent only over longer periods.

Accordingly, centering on participant means conflated a stressful period with a baseline of high stress. This idea is supported by perceived stress having an ICC of .62 and .57 in Studies 1 and 2, respectively, suggesting that there was relatively low fluctuation in stress from day to day (albeit still sufficient fluctuation, especially in suicidal ideation, to warrant a multilevel design). Examining effects relative to an individual's own baseline might be best accomplished in future studies by using longer follow-up periods.

The findings regarding participant means centered on grand means were not consistent across studies. In Study 1, we found that those who experienced a combination of high perceived stress and high fatigue across the study period, relative to the other participants, were most likely to experience suicidal ideation on any given day. In Study 2, the interaction between perceived stress and fatigue was not significant (although the effects when plotted were in the same direction as the effects in Study 1). One limitation of these analyses (but not those using grand- and participant-mean centering), however, is that the use of Level 2 predictors resulted in attenuated power because there was one Level 2 value per participant. Given this limitation, further replication with larger samples is needed to verify if these inconsistent findings are due to a lack of power or some other factor. It should be noted, however, that this issue did not affect the grand- and participant-mean centered models because they used only Level 1 effects, which capitalized on the greater power resulting from repeated daily observations.

Our findings fit well with existing theories of suicide and suggest how perceived stress and fatigue might be specifically integrated into them. As noted earlier, several theories of suicide (Baumeister, 1990; O'Connor, 2011; Shneidman, 1996) propose that suicidal thoughts arise in response to a combination of extreme perceptions of stress and a perceived inability to reduce or tolerate this stress. Our findings suggest that fatigue may be one way in which an individual's ability to tolerate stress is diminished. These findings are also compatible with vulnerability-stress theories proposing that the same level of perceived stress does not confer the same level of risk for suicide for all people on all days. Our findings suggest that fatigue may amplify the effect of perceived stress, making perceived stress more likely to confer risk for suicidal ideation on days when fatigue is high.

Our results also indicated that the increased risk associated with the co-occurrence of high perceived stress and high fatigue was specific to suicidal ideation. Perceived stress was directly associated with NSSI in both studies when using group and grand-mean centering; however, there was no interaction with fatigue in any model, suggesting that fatigue does not exacerbate the association between perceived stress and NSSI. One possible explanation is that, whereas the combination of perceived stress and fatigue increase an individual's probability of *considering* ways to escape the current situation (i.e., suicidal ideation), this combination has less utility in predicting actual behavior (i.e., NSSI) than does the amount of perceived stress on any given day. Alternatively, it may be that, because both samples were selected for their prior engagement in NSSI, the threshold to engage in NSSI was lower because this was an established and familiar behavior, whereas suicidal ideation may require a combination of perceived stressors before it emerges. The main effect of perceived stress on NSSI that we found is compatible with theories of NSSI that propose that engaging in NSSI is a maladaptive response to stress (Nock, 2010). Our findings suggest that an individual who engages in NSSI is most likely to do so on days when that person perceives high levels of stress. Our findings also suggest that the likelihood of engaging in NSSI on any given day with high perceived stress is not affected by how fatigued someone is.

These results have several broader implications. First, it is crucial that future studies test hypotheses involving daily-level processes using high-resolution methods, as there is substantial evidence that common risk factors for suicide (e.g., intense psychological pain, stressful life events, acute intoxication) fluctuate much more frequently than the dominant methodologies belie (Bagge, Glenn, & Lee, 2013; Bagge et al., 2013). Lower resolution methods that aggregate over longer periods (e.g., weeks or months) may not accurately capture the acute contexts in which the greatest risk occurs. Second, it is important to examine different forms of centering when using multilevel models because each method of centering tells us something different about the construct under study. Third, it is necessary to go beyond main effect-only models to examine models with theoretically relevant synergistic combinations of factors. Suicidal ideation and behavior likely result from several factors working together. Thus, synergistic models may have the best chance at accurately predicting these phenomena (Prinstein, 2008). Fourth, it is important to examine factors that confer (or, in our case, exacerbate) risk for suicidal ideation but not NSSI. Several studies have distinguished risk factors for suicide ideation from risk factors for suicide attempts (Auerbach, Millner, Stewart, & Esposito, 2015; Lewinsohn, Allen, Seeley, & Gotlib, 1999; Nock et al., 2008), but there has been relatively little attention paid to studies that distinguish risk factors for suicidal ideation from risk factors for NSSI.

The final and possibly broadest implication reflects the importance of reporting all analyses conducted, regardless of their potential to complicate the storyline. Although many of our findings were consistent with hypotheses across both studies, the analyses using participant-mean centering were not. Given that a case could be made supporting any of the centering choices, it could have been possible to not present these inconsistent findings (cf. researcher degrees of freedom; Simmons, Nelson, &

Simonsohn, 2011). Such a choice is not uncommon, as nearly 50% of more than 2,000 research psychologists surveyed in one study (John, Loewenstein, & Prelec, 2012) admitted that they selectively reported only the studies that supported their hypotheses. Accordingly, as suggested by Simmons et al. (2011), rather than present only the analyses that conformed to our hypotheses, we reported all analyses that we conducted, which favors accuracy over the cleanest storyline and helps to reduce publication bias in this literature.

These two studies had several strengths and limitations. The most notable strength, as discussed earlier, was the use of high-resolution methodology, which allowed us to test our hypotheses in a way that was consistent with theory. Using two samples was a strength because doing so demonstrated consistency across age groups (adolescents and young adults). Moreover, using high-risk participants (i.e., individuals who previously engaged in NSSI; Hamza et al., 2012) was a strength because it allowed us to observe sufficient variability in suicidal ideation across days and participants. This is important given the relatively low base-rate of suicidal ideation. A limitation across both studies was that we used only subjective measures of fatigue that assessed different, albeit related, aspects of the construct (Study 1 measured "fatigue," whereas Study 2 measured "energy level"). Future studies that use objective assessments of related constructs are needed (e.g., using actigraphy to assess hours of sleep). Given the need for brevity among items in intensive, microlongitudinal designs, we were unable to assess intensity or severity of suicidal thoughts and NSSI, and we were unable to assess for the specific content of suicidal thinking. In addition, both samples were recruited for a history of NSSI and may not have had suicidal ideation as severe as other higher risk groups (e.g., previous suicide attempters); thus it is unclear whether our pattern of findings would be consistent in populations without NSSI or in higher risk clinical populations. Finally, we did not have enough consecutive responses to have sufficient power to assess lagged analyses (e.g., Do fatigue and stress today predict suicidal ideation tomorrow?). Future studies should utilize multiple daily assessments of stress, fatigue, and suicidal ideation.

Finally, these findings are of particular clinical relevance. There are several effective stress-reduction interventions for adolescents and emerging adults (Biegel, Brown, Shapiro, & Schubert, 2009) that may work to reduce risk for suicidal ideation. In addition, fatigue can be addressed though interventions that improve sleep (Clarke et al., 2015), which may in turn help individuals cope with stressful days, thus reducing their risk for suicidal ideation. Our findings suggest that a combination of treatments that address both stress management and empirically supported interventions targeting sleep may be the most effective at reducing suicide risk. More broadly, these findings suggest a framework for future research to test alternate synergistic models with other factors that might influence the effect of perceived stress on fatigue. If research is directed at other modifiable factors, it would suggest clear intervention targets and appropriate times for the interventions to be used (i.e., during high stress times).

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