Examining the role of emotion differentiation on emotion and cardiovascular physiological activity during acute stress

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Abstract

Emotion differentiation (ED) -- the tendency to experience one's emotions with specificity -- is a well-established predictor of adaptive responses to daily life stress. Yet, there is little research testing the role of ED in self-reported and physiological responses to an acute stressor. In the current study, we investigate the effects of negative emotion differentiation (NED) and positive emotion differentiation (PED) on participants' self-reported emotions and cardiac-mediated sympathetic nervous system reactivity (i.e., pre-ejection period) in response to a stressful task. Healthy young adults enrolled in a two-session study. At an initial session, participants completed a modified experience sampling procedure (i.e., the Day Reconstruction Method). At session two, 195 completed the Trier Social Stress Test while cardiac impedance was acquired throughout. Linear regressions demonstrated that higher NED, but not PED, was associated with experiencing less intense self-reported negative, high arousal emotions (e.g., irritated, panicky) during the stressor (β= -.15, $p < .05$) although people with higher NED also exhibited greater sympathetic reactivity (β= .16, $p < .05$). In exploratory analyses, we tested whether the effect of NED on self-reported stress was mediated by the tendency to make internally-focus (or self-focused) attributions about performance on the task but did not find a significant indirect effect ($p = .085$). These results both complement prior work and provide a more complex picture of the role of NED in adaptive responses to stressful life events, suggesting that people with higher NED may experience their emotions as more manageable regardless of their level of physiological arousal.

Keywords: Emotion differentiation, emotional granularity, acute stress, cardiovascular physiology

Imagine giving a high-stakes presentation to your co-workers. You prepared all week, but you get up to the podium and stumble over your words. How would you feel? One factor that may impact your feelings during the performance is *emotion differentiation,* or the tendency to experience one's emotions with specificity (also known as emotional granularity) (Barrett et al., 2001; Boden et al., 2013; Erbas et al., 2019; Hoemann, Nielson, et al., 2020; Kashdan et al., 2015; Thompson, Springstein, et al., 2021). Other constructs also reflect individual differences in affective experience (e.g., emotional complexity, emodiversity, emotional clarity), but emotion differentiation uniquely captures how discretely someone experiences their emotions, separate from their beliefs or meta-cognitive awareness of their emotions (Barrett et al., 2001; Erbas et al., 2019; Hoemann, Nielson, et al., 2020; Thompson, Springstein, et al., 2021).

Considerable research demonstrates that emotion differentiation is adaptive. Individuals high in emotion differentiation experience fewer symptoms of poor mental health (Nook, 2021; Seah & Coifman, 2021; Smidt & Suvak, 2015) and engage in fewer maladaptive behaviors when exposed to stress in daily life (e.g., Anand et al., 2017; O'Toole et al., 2020; Pond et al., 2012; Seah et al., 2022; Zaki et al., 2013). Higher differentiation is also associated with experiencing daily stressors as less aversive (Nook et al., 2020; Starr et al., 2020; Willroth et al., 2020) and engaging in more frequent and more successful emotion regulation (Barrett et al., 2001; Brown et al., 2021; Kalokerinos et al., 2019). Higher differentiation is even protective for those with clinical diagnoses such as social anxiety (O'Toole et al., 2014; Seah et al., 2020). There is some evidence that the beneficial outcomes of differentiation are driven by negative emotion differentiation. When assessed separately, negative emotion differentiation (NED) predicts a range of adaptive outcomes, whereas positive emotion differentiation (PED) is more likely to yield null associations with adaptive outcomes (Demiralp et al., 2012; Erbas et al., 2014; Kashdan & Farmer, 2014; O'Toole et al., 2014; Pond et al., 2012; Willroth et al., 2020; although see Selby et al., 2014; Starr et al., 2017; Tugade et al., 2004).

Although differentiation—especially NED—is adaptive in the face of stressful life events, questions remain regarding which factors drive these effects. The theory of constructed emotion (TCE) hypothesizes that experiencing emotions as more discrete and specific may allow a person to make clearer predictions about the meaning of situational events or physiological sensations (Barrett, 2017). Indeed, people higher in differentiation exhibit a more nuanced understanding of emotion concepts (Hoemann, Fan, et al., 2020; Lindquist & Barrett, 2008; Vedernikova et al., 2021) and more context-specific physiological and behavioral responses (Hoemann et al., 2021; Kashdan et al., 2015). However, the design of many pre-existing studies presents challenges to unpacking the effects of NED on stress responding. Because these studies measure both NED and stress responding through experience sampling self-reports in daily life, they cannot rule out that individuals high versus low in differentiation may encounter qualitatively different stressful events in daily life (Hoemann et al., 2022; Ottenstein & Lischetzke, 2020). For instance, recent work demonstrates that people higher in differentiation report experiencing more diverse situations in their day (Hoemann et al., 2022; S. Lee et al., 2022). Moreover, there is some evidence that one's level of NED on any given day does not prospectively predict reduced stress levels on a subsequent day (although daily stress levels do interestingly predict reduced NED on the subsequent day; Erbas et al. 2018).

In the present study, we build on the above foundational work by examining the role of emotion differentiation in predicting both subjective and objective stress responses to a laboratory-based stressor in a two-session study. At Session 1, 250 healthy young adults completed the Day Reconstruction Method, a modified experience sampling procedure, from which we computed NED and PED. At Session 2, 221 participants returned to complete the Trier Social Stress Test (TSST), a well-validated stress induction (Allen et al., 2014; Hellhammer & Schubert, 2012; Kirschbaum et al., 1993). We then assessed participants' subjective experience immediately after the TSST as self-reported endorsements of adjectives about their current emotions and experiences of themselves and the stressor. We assessed objective experience of the stressor as sympathetic nervous system (SNS) reactivity using cardiac activity continuously recorded before and throughout the TSST. We focus on SNS reactivity because the SNS and related noradrenergic systems play a critical role in active responding during stressors via their regulation of visceromotor control, physiological and subjective arousal, and attention (Berntson et al., 2016; Cacioppo & Berntson, 1994; Obrist, 1976; Robbins & Everitt, 1995). During psychologically challenging situations (e.g., threat, motivated performance), the SNS tends to dominate influence over the cardiac cycle – increasing heart rate and vascular resistance - while the parasympathetic nervous system's influence decreases; this reciprocal relationship generates physiological and psychological arousal (Berntson et al., 1993; Weissman & Mendes, 2021). We measured SNS responding as cardiac pre-ejection period (PEP), as PEP is a relatively pure index of SNS activity. Based on pre-registered hypotheses, we tested whether NED (but not necessarily PED) would be associated with less intense self-reported stress responses. In exploratory analyses, we examined the links between NED and SNS responding. Finally, in exploratory analyses, we also examined whether participants' appraisals about the task covaried with the effect of NED on self-reported stress, as tested by cross-sectional structural equation modeling.

Method

Data Availability Statement

Data presented herein were collected as part of a larger project assessing the role of individual differences in physiology, interoception, and emotion concept knowledge on acute stress responses (see other publications with this work: (M. Feldman et al., 2022; MacCormack et al., 2022). Analyses reported in this article are secondary analyses of this dataset; none of these analyses are published elsewhere. The exploratory hypotheses addressed in this article were formally pre-registered on the Open Science Framework (OSF). The pre-registration, data and full code for analyses, diagnostics, and SI are available on OSF at https://osf.io/8wke2/.

Participants

A total of 250 healthy young adults were recruited from the University of North Carolina at Chapel Hill's introductory psychology course participant pool (57.6% female; 57.6% European American, 13.6% African American, 13.6% Asian American, 6.4% Latinx, 6.0% biracial, and 2.8% that either identified with more than one race or with none of the races presented; M_{age}= 19.20 years old, SD_{age}= 1.29 years). Participants enrolled in the study as partial fulfillment of course requirements. See MacCormack et al. (2022) for a full list of the eligibility criteria. Of the 250 participants who completed the first session, 227 participants (90.8%) returned for the second session, although 6 of the 227 either did not consent to the speech portion of the TSST (*N*=4) or withdrew their participation before the end of the task (*N*=2). Of the remaining 221 participants, 195 participants completed all measures relevant to the present analyses and had valid and complete physiological data. See Table 1 for final sample characteristics.

Table 1. ***Final sample characteristics (N= 195)***

Demographics	**n (%) or Mean**	**SD**	**Min**	**Max**
Sex[a]				
Female	113 (57.95%)	-	-	-
Male	82 (42.05%)	-	-	-
Age (years)	19.21	1.30	17.00	29.00

BMI (kg/m^2)	22.76	2.92	16.44	31.61
Race				
American Indian & Alaskan Indian	2 (1.03%)	-	-	-
Asian American	21 (10.77%)	-	-	-
Native Hawaiian or Pacific Islander	0 (0.0%)	-	-	-
African American	30 (15.38%)	-	-	-
European American	117 (60%)	-	-	-
Latin American	10 (5.13%)	-	-	-
More than one race	12 (6.15%)	-	-	-
Other	2 (1.03%)	-	-	-

[a] Participants were asked to report their gender and were given response options "Female", "Male" and "Other." SD, Min and Max are meant to represent standard deviation, minimum value and maximum value, respectively.

Procedure

All data were collected per APA ethical standards for human practices, as approved by the Institutional Review Board at the University of North Carolina at Chapel Hill (IRB# 14-3243). Participants completed two laboratory visits, each at least one week but no more than two months apart. At Session 1, participants first received informed consent and then completed a series of counterbalanced tasks. All participants completed a version of the Day Reconstruction Method (DRM; Kahneman et al. 2004), a form of experience sampling method from which we estimated NED and PED. Besides these measures, participants completed some additional measures that are reported elsewhere (see MacCormack et al., 2022).

Upon returning for Session 2, participants were connected to an electrocardiograph and impedance cardiograph monitor for a 5-minute resting baseline acquisition period. After the baseline acquisition, participants were then provided with a second informed consent document as required by the UNC-CH IRB. This document told subjects that they would be completing a series of cognitive behavioral tasks that included public speaking. Consenting participants completed the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). The TSST is a well-validated, ecologically valid stress induction that produces reliable changes in self-reported negative, high arousal affect and sympathetic nervous system reactivity as participants perform an impromptu speech and math task in front of a panel of impassive interviewers (Allen et al., 2014; Hellhammer & Schubert, 2012; Kirschbaum et al., 1993).

The TSST consists of three components: a speech preparation phase (2 minutes), a speech task (10 minutes), and a math task (5 minutes). Experimenters told participants they would complete a 10-minute speech for a hypothetical "preliminary interview for a desirable job in [their] specific area of interest." Experimenters then introduced two "interviewers" whom they were told were "experts in nonverbal communication, public performance, and cognitive ability." Interviewers dressed professionally and wore white laboratory coats over their clothing. After the instructions, participants were given 2 minutes alone to mentally prepare for the speech. After the preparation phase, interviewers re-entered the testing room. During the speech task, participants were required to talk for the full 10 minutes; interviewers prompted participants to continue speaking if they paused for more than 10 seconds. After the 10-minute speech, interviewers introduced an impromptu mental math task: counting backwards from the number 996 in steps of 7 as fast as possible while making as few errors as possible. If participants made a mistake, they were told to start again at 996. The task was modified systematically for participants who found the math too easy or too difficult. Interviewers ended the task after 5 minutes, although participants were not told how long they would have to complete the math task. Continuous changes in cardiac physiology were acquired throughout the preparation, speech, and math phases. Following the TSST, participants reported on their subjective experiences (see Session 2 measures) during the task. At the end of the session, all participants were debriefed. See SI for the full TSST script.

Session 1 Measures

Assessing differentiation: Modified Day Reconstruction Method. Participants completed a modified version of the Day Reconstruction Method (DRM) as an experience sampling measure of their emotional experiences throughout the day prior. The DRM was designed to assess situation-specific experiences as an alternative to more burdensome ecological momentary assessments that contact participants "in the field" during daily life (Diener & Tay, 2014; Dockray et al., 2010; Kahneman et al., 2004). The DRM's focus on situated experiences is thus thought to prevent many of the retrospective memory biases invoked in measures that assess a person's general tendency to experience emotions as discrete and specific (e.g., the Range and Degree of Emotional Experience Scale; Kang & Shaver, 2004). Although not identical, prior work suggests that affect ratings on the DRM correlate moderately with those collected via ecological momentary assessment (Diener & Tay, 2014; Dockray et al., 2010). The DRM has also been used to compute differentiation estimates, which in turn was related to individual differences in brain activity to affective images (J. Y. Lee et al., 2017).

In the version of the DRM used for this study, participants were asked to recall at least three and up to five episodes from the morning, afternoon, and evening of the previous day for a total of 9-15 episodes per participant. Specifically, participants were instructed to "try to remember each episode of [their] day in detail and write a few words that will help remind [them] of exactly what was going on." See SI for full instructions. Participants in the final sample reported an average of 11.87 (SD=2.10) episodes. Examples of reported episodes from participants included events such as "woke up at 8:50 and couldn't take a shower"; "stressed about registration, eager for exam to be over"; "upset from loss in Natl. Championship"; "picked [Name] up and went to movies"; "talked with a couple friends"; "relaxed and browsed reddit"; "snacking and T.V." For each reported episode, participants were asked to rate the extent to which they experienced 20 emotions (“amusement”, “anger”, “anxious”, “awe”, “bittersweet”, “boredom”, “contentment”, “disgust”, “embarrassed”, “excitement”, “fear”, “gratitude”, “guilt”, “happiness”, “irritable”, “jealous”, “love”, “pleased”, “proud”, “sadness)” *during* the episode on a scale from 1 (“not at all”) to 7 (“very much”). Items were selected to sample the four quadrants of the affective circumplex (i.e., negative valence-high arousal, negative valence-low arousal, positive valence-high arousal, and positive valence-low arousal (Feldman, 1995).

Differentiation calculations. Computationally, emotion differentiation is the degree to which people tend to endorse relatively few versus many emotion adjectives across multiple instances of reporting (Barrett et al. 2001). Participants’ emotion endorsements from the DRM were used to calculate indices of NED and PED. Following previous recommendations, we computed intra-class correlations (ICCs) to derive an index of the relatedness of same-valence emotion endorsements (see Lindquist & Barrett, 2008; e.g., Tugade et al., 2004; Thompson et al. 2019). We treated positive valence emotion terms and negative valence emotion terms as separate classes, computing separate ICC values for positive and negative emotion with the logic that negative emotion differentiation (NED) and positive emotion differentiation (PED) may produce different outcomes, especially in the face of stress (e.g., O’Toole et al., 2020; Thompson et al., 2021; Tugade et al., 2004; Willroth et al., 2020).

Just as an ICC assesses the consistency of, or correlation amongst, scale items across individuals, an ICC can also assess the consistency of same-valence emotion endorsements across instances within an individual. In the case of differentiation, a high correlation amongst emotion adjectives across instances suggests that a person tends to frequently co-endorse multiple same-valence emotion categories at the same time; that is, a person may frequently endorse feeling “sad,” “angry” and “anxious” all at once. This lack of specificity is inferred to indicate low differentiation, or that this person does not differentiate amongst same-valence emotion adjectives. In contrast, someone high in differentiation may co-endorse "anger" and "anxiety" in one context, but only report "anger" in another. This specificity suggests that this person experiences their emotions with relative precision across situational instances (see Thompson et al. 2019).

We calculated ICCs with absolute agreement to account for both the correlation between ratings and the magnitude of the ratings (Giraudeau, 1996; Shrout & Fleiss, 1979, although it is worth noting that across the literature, differentiation scores calculated with absolute agreement and with consistency are highly correlated (*r*s= .95-.99, Erbas et al., 2014; Thompson et al., 2021). ICCs are theoretically bounded between 0 to 1 but negative ICCs are possible when computing emotion differentiation (see Thompson et al. 2019 for a discussion). In these cases, researchers often re-code negative ICCs as 0 (i.e., indicating low differentiation) based on Cohen, Cohen, West and Aiken's (2003) recommendations for interpreting negative ICCs (e.g., Anand et al., 2017; Hoemann, Fan, et al., 2020; Thompson, Liu, et al., 2021); see Thompson et al. 2019 for a discussion). However, it should be noted that some researchers opt to exclude participants with negative ICC values (e.g., Kalokerinos et al., 2019) and that researchers' analytic choices surrounding negative ICC's could impact results (Thompson et al. 2019). Thompson et al. (2019) thus recommend that researchers are explicit about their choice to recode versus exclude participants with negative ICCs and additionally characterize those participants whose ICCs systematically cannot be computed versus those whose can (see SI). We opted to recode as 0 and retain those participants with negative ICCs in our sample for two reasons. First, 37 participants in our sample had negative ICC values, perhaps because our daily diary method sampled a single day and not a series of days as in some methods using ecological momentary assessment. Second, our follow-up characterization of these participants revealed that those individuals with negative ICC values reported significantly fewer negative emotion adjectives per instance when compared with those with positive ICCs (see SI); this feature of reporting is consistent with the definition of high emotion differentiation and suggests that these individuals may be reporting their negative emotions more precisely than those who are endorsing multiple negative emotions per reporting instance. Throughout the main text, we therefore report findings including those participants with negative ICCs recoded as 0 but for transparency, we report models excluding participants with negative ICCs in the SI. In all models reported, ICC values were Fisher *r*-to-*z* transformed to fit a normal distribution and multiplied by -1 for ease of interpretation; thus, higher values in our analyses reflect higher differentiation.

Mean affect covariates. Following previous literature, we computed an index of participants' mean negative and positive affect by averaging ratings for negative or positive emotions reported across measurement instances on the DRM. Higher scores on this index indicate greater levels of mean affect. We included mean negative affect as a covariate in our regression analyses because differentiation is significantly associated with general emotionality (i.e., you cannot demonstrate differentiation of emotions if you do not experience events as emotional; Boden et al., 2013; Dejonckheere, 2019; Erbas et al., 2019)**.**

Session 2 Measures

Assessing self-reported stress experiences. We assessed individuals' self-reported experiences in response to the stressor in two ways. Our primary outcome of interest here was self-reported emotional experience during the stressor, while the secondary, more exploratory outcome was participants' appraisals of the stressor.

Self-reported emotion. Following the TSST, participants completed an expanded 30-item version of the Positive & Negative Affect Schedule (Watson & Clark, 1994). Like the items used in the modified DRM, items were selected to range the full affective circumplex (e.g., Feldman, 1995) with an expanded selection of negative, high arousal emotion items given that we expected the task to induce acute stress. Specifically, 17 items were high arousal emotions (e.g., excited, stressed; $\propto$= .86), 9 were low arousal emotions (e.g., bored, serene; $\propto$= .51), 16 were negative emotions (e.g., embarrassed, stressed, bored, sad*;* $\propto$= .91) and 9 were positive emotions (e.g., excited, proud, serene; $\propto$= .86). Participants rated the intensity with which they experienced each emotion term on a scale from 0 (“not at all”) to 6 (“extremely”). Since we were interested specifically in subjective stress responses, we computed an average of each participants' ratings for 15 negative-high arousal emotion items (a = .88), with higher average ratings indicating more intense negative, high arousal emotion in response to the TSST. These items were “activated”, “afraid”, “alert,” “angry”, “annoyed”, “anxious”, “disgusted”, “distressed”, “embarrassed”, “frustrated”, “guilty,” “hyperactive”, “irritable”, “panicky”, and “stressed.”

Exploratory individual difference: Internal vs. external focus attributions. Many theories of emotion (e.g., Barrett et al., 2007; Clore, Gasper, & Garvin, 200; Lambie & Marcel, 2002; K. Lee, 2018; Lerner & Keltner, 2000; Lindquist, 2013) and prior empirical work (e.g., Lee et al., 2018) suggest that emotional experiences can be experienced as a property of one's internal state (e.g., self-focused emotion, “I feel overwhelmed”) but also as a property of the external environment (e.g., world-focused emotion, “The situation is threatening”). As an exploratory measure of participants' internal and external-focused experiences following the TSST, participants indicated how much they experienced 25 negative adjectives that could describe the self (e.g., “failure”) or the situation (e.g., “unfair”) on a scale from 0 (“not at all”) to

6 (“extremely”). These items were “abandoned”, “challenged”, “cheated”, “defeated”, “failure”, “incompetent”, “insulted”, “lonely”, “mistaken”, “offended”, “overwhelmed”, “rejected”, “threatened”, “thwarted”, “transgressed”, “uncertain”, “uneventful”, “unfair”, “uninterested”, “unknown”, “unresolved”, and “vulnerable.” This measure was also used and validated in a randomized control trial with the beta-blocker propranolol, where we found that propranolol administration blunted SNS reactivity and negative, high arousal emotion self-reports in response to the TSST but not endorsements on this measure (MacCormack et al., 2021). We thus take this to be a measure that is complementary to, but distinct from, the subjective emotion reports.

To test whether adjective ratings indeed conformed to internal- and external-focused latent factors we ran exploratory factor analyses using the packages *`parameters`* (Lüdecke et al., 2020), *`psych`* (v2.0.7; Revelle,2019), and *`GPArotation`* (v2014.11-1; Bernaards & Jennrich, 2014). Given that self- and world-focused experiences of emotion are expected to covary within situations (Dewey, 1895; Lambie & Marcel, 2002), we used the oblique promax rotation to establish the final solution (Hendrickson & White, 1964). Diagonally weighted least squares estimation was used to account for non-normality of the response distribution (Li, 2016). As is standard, we conducted a series of model iterations and examined fit statistics to evaluate model fit (see SI for details). Examination of a scree plot of the observed eigenvalues suggested that two factors should be extracted. We ran a two-factor solution which explained a cumulative 49% of the variance in the data and demonstrated adequate model fit, $\chi^2 = 27.46$, $p= .0012$; TLI= .91, RMSEA = .09, 90% CI [.05, 0.13]; RMSR = .06 (see SI for factor loadings). Factors loadings suggest that the first factor reflected participants’ *external attributions* or world-focused experiences (i.e., participants’ experience that the situation was threatening, offending, unfair, or involved transgression). The second factor reflected participants’ *internal attributions* or self-focused experiences (i.e., participants' experience that they were failures, incompetent, vulnerable, or that they felt overwhelmed). We then extracted factor scores from the estimated latent variables to use in subsequent regression and structural equation model path analyses (Skrondal & Laake, 2001)

Assessing psychophysiological arousal. To assess sympathetic nervous system (SNS) arousal in response to the TSST, continuous electrocardiography and impedance cardiography data were acquired using Mindware Technologies (Gahanna, OH, USA) Biolab software. Electrocardiography data (ECG) were acquired from three non-invasive spot electrodes – one placed on the right collarbone (-) and two on either side of the lowermost ribs (+ and ground). Impedance cardiography data (ICG) were acquired using the four-spot electrode configuration. Two spot electrodes were placed on the participant's front torso, one at the base of the neck (+) and one at the bottom of the sternum (-); and two electrodes were placed on the participant's back, about 4 cm above the base of the neck and below the bottom of the sternum. Trained research assistants visually inspected and independently scored all segments of data (in 60 seconds bins) using Mindware Technologies' Heart Rate Variability (v3.021) and Cardiac Impedance (v3.2.4) analysis software according to field recommendations (Jennings & Allen, 2016; Sherwood et al., 1990). Disagreements were resolved by an expert (JKM). Initial agreement between scorers was 93.7% for ECG (based on the number of R-spikes identified per segment) and 85.3% for ICG (based on pre-ejection period values per segment).

Cardiac-mediated SNS reactivity. We focus on pre-ejection period (PEP) as it is a reliable and widely used index of cardiac-mediated SNS activity (Newlin & Levenson, 1979). Cardiac PEP is derived from electrocardiography and impedance cardiography data and reflects the time (in milliseconds) between depolarization of the left ventricle and the opening of the aortic valve. Shorter, or smaller, PEP values suggest faster periods of cardiac contractility as influenced by the sympathetic nervous system; on the other hand, larger PEP values suggest slower periods of cardiac contractility, such as when people are more relaxed.

SNS reactivity during the TSST was calculated by averaging across PEP activity in the first minute of each stress phase (preparation, speech, and arithmetic periods) and subtracting that average from the PEP activity in the last minute of baseline. If participants were missing data during the first minute of these sections (e.g., if the experimenter forgot start recording the physiological data at the start of the TSST), the second minute was substituted. To improve the interpretability of PEP values, we multiplied PEP values by -1 such that greater PEP values are equivalent to an increase in cardiac SNS activity from resting baseline and lower PEP values are equivalent to a decrease in cardiac SNS activity from resting baseline. Twenty-one out of 221 participants who completed sessions one and two were excluded from analyses for missing PEP data due to hardware issues (i.e., the team ran out of electrodes; electrode(s) stopped adhering to the skin during task; data was improperly saved) or poor physiological signal quality (i.e. R-spike in ECG signal or B-point in dZ/dt signal could not be estimated). As part of data preparation, we examined outliers +/- 3SDs from the mean for PEP within each phase of the TSST. No outliers were identified.

Analytic Approach

Power analysis. Effect sizes for power analyses were determined based on prior literature. Prior studies that have found a significant main effect between negative emotion differentiation and averaged emotion ratings observed small-to-moderate effects (e.g., r= .47 in Barrett et al., 2001; r= -.22 and -.28 in Boden et al., 2013; r= .39 in Dejonckheere et al., 2019; r = -.26 in Erbas et al., 2019). Meta-analyses that have found significant main effects between measures of cardiovascular reactivity and emotion ratings also demonstrate small-to-moderate associations (*rs*~ .10-.50, Campbell & Ehlert, 2012). A post-hoc sensitivity analysis in G*power (Faul et al., 2007) suggested that a sample of N=197 with eight predictors would have 0.98 power to detect a small effect size (f^2= .15).

Hypothesis testing. To test whether emotion differentiation predicts stress responses to the TSST, we conducted hierarchical multiple regressions using the `*stats*` package (v4.0.2). In the first model step, we entered NED and PED together to assess the unique variance in the primary stressor outcomes (TSST negative, high arousal emotions, SNS reactivity) contributed by NED vs. PED. We include PED here to explore its influence on responses to acute stress based on evidence that trait-level PED may play a role in coping behaviors during stress in daily life (Tugade et al., 2004). For instance, Tugade et al. 2004 found that PED is associated with more adaptive coping strategies (less distraction and more behavioral disengagement) during stress and more deliberative and less automatic coping style. In the second model step, we added the covariates of age, self-identified sex, and DRM mean negative and positive affect in line with prior studies of emotion differentiation (e.g., Willroth et al., 2019) and responses to the TSST (e.g., M. Feldman et al., 2022; Kudielka et al., 2004; MacCormack et al., 2021, 2022). In the model with SNS reactivity as the criterion, BMI was included as a covariate given prior findings that greater adiposity is related to blunted SNS activity (e.g., Carroll et al., 2008; Steptoe & Wardle, 2005).

Model predictors were mean centered to improve the interpretation of intercepts. Model outcome variables (TSST negative high-arousal emotion and SNS reactivity) were normally distributed. Standardized betas (b) and semi-partial correlations (sr^2) as unique effect estimates while R^2 serves as the joint effect estimates. We used a two-tailed test of significance at α = .05.

We considered observations with residuals greater than +/- 3 SD to be multivariate outliers and observations with Cook's distance (D_i) greater than the 10th percentile of the *F*-statistic distribution for each model to have undue influence. The final models were checked for multicollinearity, linearity of predictors, normality of residuals, homoscedasticity, and cases with concerning influence. No observations demonstrated unique influence in the reported models; however, a few observations demonstrate large residuals or high leverage. Removing these observations did not alter the significance of the results. See SI for regression models without observations with large residuals or high leverage. See Table 3 for descriptive statistics for all model variables and Table 4 for bivariate correlations between model variables.

Table 3. ***Descriptive statistics for independent and dependent variables***

Measures	M	SD	Scale	Min	Max	Skew	Kurtosis
Differentiation							
NED	-.46	.33	-	-1.41	.00	-.39	-.32
PED	-.97	.38	-	-2.35	.00	.02	.53
Affect covariates							
Mean negative affect	.48	.35	1.00- 7.00	.07	2.91	2.55	11.59
Mean positive affect	1.26	.71	1.00- 7.00	.07	4.64	1.49	3.96
Self-reported stress experiences							
Post-TSST negative-high arousal emotion[a]	2.07	1.29	.00 - 6.00	.00	5.27	.48	-.63
Exploratory individual differences							
Post-TSST external attribution appraisals factor score[a]	-.03	.90	-	-.72	6.09	2.99	12.42
Post-TSST internal attribution appraisal factor score[a]	-.02	.96	-	-1.54	2.18	.40	-.86
Physiological responses throughout stressor							
SNS reactivity (inversed pre-ejection period)	-10.59	11.50	-	-24.67	53.33	0.50	0.91

N=197 *M*, *SD*, Min and Max are meant to represent mean, standard deviation, minimum value and maximum value, respectively. Scales are provided for self-report measures, except for the appraisal factor scores. Descriptive statistics for negative emotion differentiation (NED) and positive emotion differentiation (PED) were computed prior to ICCs being Fisher-z transformed. [a]*N* = 195

Table 4. ***Bivariate correlations between, mean affect in daily life, emotion differentiation***

Measures	1	2	3	4	5	6	7
1. NED							
2. PED	.10						

3. Mean neg affect	**-.30****	**-.22****					
4. Mean pos affect	-.08	**-.31****	**.23****				
5. Neg-high arousal emotion	**-.15***	-.00	**.18****	.00			
6. External	-.09	-.04	**.18***	.07	**.61****		
7. Internal	-.10	**-.06***	**.17****	.03	**.81****	**.64****	
8. SNS reactivity	**.16***	.09	-.01	-.07	.05	.02	.06

N = 195. Significant items are bolded, with *p< .05, **p<.01.

Results

NED and PED in relation to self-reported emotions during the stressor

Consistent with the hypothesis that higher NED from Session 1 would predict less intense negative, high arousal emotion during the stressor at Session 2, there was a significant main effect of NED on self-reported negative, high-arousal emotions (β= -.17, p < .05). Participants who reported their negative emotions with more precision on the DRM (higher NED) reported experiencing less intense negative, high arousal emotions (e.g., feeling anxious, angry, frustrated) during the acute stress induction. However, this effect did not remain statistically significant when covariates were added to the model (p = .065; see Table 5). Sex was significant, indicating that self-identified male participants reported less intense negative, high arousal emotion after the stressor compared to self-identified females (β = -.25, p < .01). Higher levels of mean negative affect on the DRM also predicted higher TSST negative high arousal emotion (β= .18, p < .05). Neither PED, age nor mean level of DRM positive affect were associated with TSST negative, high arousal emotion. (*p*s >.10). Finally, the addition of model covariates resulted in a significant model change (ΔR^2 = 0.13**, 95% *CI* [.03, .20]). We note that the effect of NED on negative, high-arousal emotion reports remained negative but did not reach statistical significance in the model in which individuals with negative ICC scores were excluded (see SI).

Table 5. ***Regression results using negative, high-arousal emotion reports as the criterion***

Predictors	***b***	***b* [95% CI]**	***β***	***sr²***	***sr²* [95% CI]**	**Fit *R²* [95% CI]**	**Difference Δ*R²* [95% CI]**
Step 1							
(Intercept)	1.68**	[1.15, 2.22]					
NED	**-0.65***	**[-1.19, -0.12]**	**-.17**	**.03**	**[-.02, .08]**		
PED	-0.05	[-0.52, 0.43]	-0.01	.00	[-.00, .00]		
						R^2 =.030 [.00, .09]	
Step 2							
(Intercept)	2.07**	[1.50, 2.65]					
NED	-0.50	[-1.04, 0.03]	-0.13	.02	[-.02, .05]		
PED	-0.01	[-0.50, 0.47]	-0.00	.00	[-.00, .00]		
Mean neg affect	**0.68***	**[0.15, 1.21]**	**0.18**	**.03**	**[-.01, .07]**		
Mean pos affect	-0.10	[-0.35, 0.16]	-0.05	.00	[-.01, .02]		
Sex	**-0.64****	**[-0.99, -0.28]**	**-0.25**	**.06**	**[-.00, .12]**		
Age	-0.10	[-0.23, 0.04]	-.10	.01	[-.02, .03]		
						R^2 =.13** [.03, .20]	ΔR^2 =.10** [.02, .18]

N = 197. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. R^2 represents the unadjusted proportion of the variance for the criterion. *$p < .05$, $p < .01$

NED and PED in relation to SNS reactivity during the stressor

Although not statistically significant in the first model step ($p = .058$), NED was associated with cardiac SNS reactivity when controlling for model covariates ($\beta = .17$, $p < .05$), such that participants in our sample who reported more precise negative emotion during the DRM exhibited higher cardiac SNS reactivity during the TSST. PED did not significantly covary with SNS reactivity ($p > 0.10$). However, age was positively associated with SNS reactivity ($\beta =$ .18, $p < .05$). Mean negative affect and mean positive affect on the DRM, sex, and BMI also were not associated with SNS reactivity (*p*s > .05). Moreover, the addition of the covariates resulted did not result in a significant model change (ΔR^2 = .06, 95% *CI* [-.00, .11]). The effect of NED on SNS reactivity remained positive and statistically significant in the model in which individuals with negative ICC scores were excluded (see SI).

Table 6. ***Regression results using SNS reactivity as the criterion***

Predictors	***b***	***b*** **[95% CI]**	***β***	***sr²***	***sr²*** **[95% CI]**	**Fit *R²*** **[95% CI]**	**Difference Δ*R²*** **[95% CI]**
Step 1							
(Intercept)	0.40	[-0.02, 0.82]					
NED	0.41	[-0.01, 0.83]	0.15	.02	[-.02, .06]		
PED	0.23	[-0.15, 0.60]	0.09	.01	[-.02, .03]		
						R^2=.028* [.00, .08]	
Step 2							
(Intercept)	0.42	[-0.05, 0.89]					
NED	**0.51***	**[0.08, 0.94]**	**0.17**	**.03**	**[-.02, .07]**		
PED	0.25	[-0.14, 0.65]	0.10	.01	[-.02, .03]		
Mean neg affect	0.20	[-0.23, 0.63]	0.07	.00	[-.01, .02]		
Mean pos affect	-0.07	[-0.28, 0.13]	-0.05	.00	[-.01, .02]		
Sex	0.15	[-0.14, 0.43]	0.07	.01	[-.01, .02]		
Age	**0.14***	**[0.03, 0.25]**	**0.18**	**.03**	**[-.02, .07]**		
BMI	-0.03	[-0.08, 0.02]	-.08	.01	[-.02, .03]		
						R^2 =.079** [.00, .13]	ΔR^2 =.06 [-.01, .11]

N = 195. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. R^2 represents the unadjusted proportion of the variance for the criterion. * $p < .05$. **, $p < .01$.

Cross-sectional effects of NED on stress-outcomes through internal appraisals

Finally, we performed post-hoc exploratory analyses, to explore the finding that those high in NED had greater SNS activity but not necessarily reduced self-reported negative, high arousal affect. We thus regressed NED and PED on participants' appraisals during the stressful task to examine if NED was associated with differences in the content of participants' psychological experiences during the task. We focused on internal attributions given that internal attributions of control are known to more strongly predict stress reactivity than external attributions of control (e.g., Krause & Stryker, 1984). Specifically, we tested the indirect effect of NED through self-focused experiences on negative high arousal emotion in a 5,000-sample bootstrapped structural equation model using the `*lavaan*` package (v0.6-11; Rosseel et al., 2022).

The indirect effect of NED on negative high-arousal self-reported emotion through internal attributions was not statistically significant (indirect effect: b = -.38, 95% CI = [-.83, .04], p = .085; total effect: b = -.60, 95% CI = [-1.11, -.11], p = .02). However, the direct effect of NED on negative high-arousal emotion did not remain significant after controlling for self-focused experiences (p = .21), suggesting that having relatively fewer internal-focused attributions may account for part of the relationship between higher NED and less intense negative high arousal emotion. See SI for full model results. However, it should be noted that we were likely underpowered to detect such an effect. Indeed, there was no relationship between NED and internal attributions in the reduced sample excluding participants with negative ICC values. Moreover, this path model is cross-sectional and should not be interpreted causally. However, it may begin to provide a fuller picture of how the features of stressful experiences may differ for those individuals relatively higher versus lower in NED.

Discussion

It is well-established that experiencing more nuanced and differentiated emotions (i.e., emotion differentiation) is associated with more adaptive emotional and behavioral responses to stress— yet others have pointed out challenges associated with identifying mechanisms underlying this relationship (e.g., Hoemann, Khan, et al., 2020; E. Nook, 2021; Ottenstein & Lischetzke, 2020; Thompson et al., 2021). To date, research on emotion differentiation in the context of stress has mainly focused on the link between differentiation and responses to stressors that are experienced as part of daily life. While this rich literature provides vital information as to how emotion differentiation may operate across a range of situations and contexts, herein we explore effects of negative emotion differentiation (NED) on both subjective and objective responses to stress in a highly controlled, standardized laboratory procedure.

Consistent with our hypotheses, we found that NED buffered against negative, high-arousal emotions (e.g., feeling “afraid,” “irritated,” etc.) during the TSST in our full sample of participants, including those who had negative ICC values recoded to indicate high emotion differentiation. Prior work suggests that labeling previously ambiguous affect with a discrete emotion word attenuates negative emotion, particularly during stressful contexts. For instance, studies of exposure therapy interventions find that participants who were instructed to label their affect exhibited lower physiological responses relative to control groups during the exposure, although groups did not differ on self-report measures (Kircanski et al., 2012; Niles et al., 2015). Interestingly, we found the opposite pattern of results, where individuals higher in NED still experienced greater SNS reactivity to the stressor. Interestingly, the pattern of responses in our study replicates findings that heightened physiological responses accompanied by relatively lower reported negative affect (repressive coping or affective-autonomic response discrepancy, Bonanno et al., 1995) is associated with better psychosocial adjustment across a variety of stressful contexts including bereavement (e.g., Bonanno et al., 1995; Coifman et al., 2007; although see Kohlmann et al., 1996). Greater SNS reactivity coupled with less self-focused experience (i.e., lower internal attributions) may also indicate that individuals higher in NED experienced a psychophysiological state more akin to a “challenge” state (vs. a “threat” state) during the stressor, although we did not have the full suite of physiological dependent variables (e.g., total peripheral resistance) to formally test this hypothesis in the current study. “Challenge” states are associated with more adaptive cardiovascular functions wherein the individual perceives they have sufficient resources to cope with present demands (Blascovich & Mendes, 2010; Wormwood et al., 2019).

Nearly all theoretical accounts of emotion agree that emotions are most adaptive when they are highly differentiated and specific to a given situation. Decades of research demonstrate that individuals differ widely in how discretely they experience their emotions, with some experiencing emotions as categorically distinct (e.g., anger vs. fear vs. disgust) and others as more diffuse states (e.g., unpleasantness). According to active inference models of emotion such as the theory of constructed emotion, people experience emotions as discrete and specific when their brains use context-specific knowledge to make meaning of internal and external sensations while predicting what actions may be needed to respond (Barrett, 2017; Lindquist, 2013). In this view, emotion predictions are *ad hoc concepts* (Barsalou, 2003; Wilson-Mendenhall et al., 2011), or groups of whole-brain representations that fit the situation and guide action. Individuals higher in differentiation may therefore be better able to use emotion concepts to predict adaptive actions in evocative contexts. Consistent with this hypothesis, results from neuroimaging studies suggest shown that higher emotion differentiation is associated with more efficient patterns of neural activity during emotion (J. Y. Lee et al., 2017; Wang, Shangguan, et al., 2020). It may also be the case that individuals higher in differentiation are updating existing concepts and form new emotion concepts readily (Wang, Liao, et al., 2020). Greater precision and ease of forming reliable concepts would likely manifest as experiencing instances of emotions as specific and distinct, but perhaps also as more manageable.

Other research demonstrates that low NED is associated with self-reported emotion regulation difficulties (Barrett et al., 2001; Kalokerinos et al., 2019; O'Toole et al., 2014; Tong & Keng, 2017) while higher NED is associated with greater emotion regulation success

(Kalokerinos et al., 2019; Ottenstein, 2020). However, recent evidence fails to show links between higher NED and the selection of specific adaptive regulation strategies, like problem-solving (Brown et al., 2021; Kalokerinos et al., 2019; M. S. O'Toole et al., 2021). People higher in NED may be constructing experiences that are qualitatively different from those low in NED. Other research suggests that individuals high in differentiation are more likely to engage in appraisals that reflect "wise reasoning," or a tendency to engage in intellectual humility, self-transcendence, consideration of other's perspectives, and compromise throughout daily life (Grossmann et al., 2019). Our findings build on these other findings to suggest that those higher in NED may be constructing different meanings around stressors, and as a result, experience their emotions as less self-relevant than those lower in NED.

Although some prior work finds that PED is associated with adaptive behaviors in the context of psychopathology (e.g., Selby et al., 2014), we did not find that PED predicted self-report or physiological responses in the context of acute stress. Although positive emotions are relevant for intrinsic motivation (Vandercammen et al., 2014) and prompting exploration (Fredrickson, 2001; Huppert et al., 2004), NED may be particularly relevant in this context simply because people are more likely to experience unpleasantness in the presence of an acute stressor. That said, it may be the case that NED has greater predictive validity in the context of stress than PED because experiencing precise negative states may help improve negative state management. Indeed, negative valence is thought to carry greater informational urgency, in turn motivating action more efficiently (Barrett et al., 2001; Hesp et al., 2019).

While our findings help advance the literature on emotion differentiation, they should nonetheless be seen as preliminary for multiple reasons. First, findings should be viewed as preliminary considering caveats associated with the design and analysis of our study. We relied on a healthy, young adult, university participant pool sample. Additionally, our measure of emotion differentiation was unique: Unlike studies that use ecological momentary assessments to measure differentiation across many days, our measure was based on participants' reports of events from the day prior. Finally, there are caveats associated with the laboratory itself: participants' awareness of constant observation or the clinical nature of the laboratory environment may limit the external validity of the results.

Third, our analytic decisions about negative ICC values impacted our findings, as can be the case in the emotion differentiation literature. Negative ICC values can occur when computing emotion differentiation and are the product of measurement error. However, these occurrences are not thought to reflect noise per se, but to occur when participants are high differentiators (see Thompson et al. 2019). We opted to recode negative ICCs as 0 in our sample, as is common in the literature (see Thompson et al. 2019). Nonetheless some researchers opt to exclude these participants (e.g., Kalokerinos et al., 2019). We retained recoded negative ICC values for a few reasons. First, we followed statistical recommendations for interpreting negative ICC's, more generally (Cohen et al. 2003). Second, we our own follow-up analyses suggested individuals with negative ICCs in our sample were indeed reporting fewer negative emotion adjectives per instance—and thus reporting their negative emotions in a more precise manner—than those with positive ICCs (see SI). Finally, we recoded, as opposed to exclude participants because we wished to retain statistical power. Nonetheless, because our analytic choices resulted in different outcomes when participants with negative ICCs were included versus excluded, the present findings should be interpreted with caution prior to further replication.

Although our study has caveats, some design features are also strengths. Our healthy sample ruled out the role of other comorbidities, our method of assessing differentiation reduced participant burden and allowed us to retain a large sample, and the laboratory-based stressor was highly controlled and unfolded in the same way for all participants. Our design also allowed us to assay differentiation and stress responding on separate days—suggesting that findings are not due to day-of effects. Future work should replicate these findings with different measures of differentiation (e.g., across many days; with open-ended responses) and in more representative samples. Nonetheless, the fact that our laboratory-based measures replicate the effect of NED on stress responding in adult (Kashdan et al., 2015; O'Toole et al., 2020; Thompson, Springstein, et al., 2021), adolescent (Nook et al., 2020), and psychiatric (Seah & Coifman, 2021; Smidt & Suvak, 2015) samples is compelling.

Conclusions

In sum, we found that greater negative emotion differentiation was associated with reduced emotional intensity in response to an acute laboratory stressor, even in the face of relatively increased physiological arousal. This effect was partially explained by the tendency to make fewer internal, self-blaming appraisals throughout the stressor. Consistent with the theory of constructed emotion, these findings suggest that more specific and nuanced experiences of emotion help people more adaptively meet the demands of a stressful situation.

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Supplementary Information

Table of Contents

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Table S1. ***Sample characteristics compared by subjects included vs. excluded from final analyses***

Demographics	**Included Group (*N* or Mean)**	**Excluded Group (*N* or Mean)**	***p*-value**
Sex[a]			.88
Female	113 (57.36%)	31 (58.49%)	
Male	84 (42.64%)	22 (41.51%)	
Age (years)	19.20	19.23	.89
BMI (kg/m^2)	22.75	22.81	.89
Race			.38
American Indian & Alaskan Indian	2 (0.01%)	1 (1.89%)	
Asian American	23 (11.68%)	11 (20.75%)	
Native Hawaiian or Pacific Islander	0 (0.0%)	0 (0.0%)	
African American	30 (15.22%)	4 (7.55%)	
European American	117 (59.39%)	27 (50.94%)	
Latin American	11 (5.58%)	0 (0.0%)	
More than one race	12 (6.09%)	3 (5.66%)	
Other	2 (1.02%)	1 (1.89%)	
Did not provide	0 (0.0%)	1 (1.89%)	
NED	-.40	-.41	.45
PED	-.70	-.75	.47

[a] Participants were asked to report their gender and were given response options "Female", "Male" and "Other." Difference tested with Pearson's chi-square for categorical measures and independent samples t-test for continuous measures.

Post-Trier Social Stress Test Appraisals

Good model fit in factor analysis is generally represented by non-significant chi-square (although significance values for chi-square tests can be inflated with large sample sizes), Tucker Lewis Index (TLI) ≥ .90, root mean squared error of approximation (RMSEA) ≤.08, comparative fit index (CFI) ≥ .95, and root mean square of the residuals (RMSR) values < .05 (Cangur & Ercan, 2015; Hu & Bentler, 1999). Rather than weight one or two fit indices more heavily in our inferences criteria, it is typical to include all fit indices to provide a holistic evaluation of model fit.

Table S2. ***Exploratory factor analysis focused on appraisals***

	World-focused	**Self-focused**
Abandoned	**.77**	-.09
Cheated	**.65**	.06
Insulted	**.54**	.24
Lonely	**.62**	.10
Offended	**.54**	.12
Rejected	**.61**	.15
Threatened	**.75**	-.10
Thwarted	**.73**	-.10
Transgress	**.94**	-.15
Uneventful	**.55**	-.06
Unfair	**.59**	.14
Uninterested	**.41**	-.07
Unknown	**.42**	.16
Unresolved	**.53**	.07
Challenged	-.10	**.74**
Defeated	.14	**.73**
Failure	-.08	**.90**
Incompetent	.01	**.80**
Mistaken	-.13	**.83**
Overwhelmed	.04	**.76**
Uncertain	.00	**.76**
Vulnerable	.13	**.66**
Total		
SS loadings	5.73	5.08
Proportion of variance	.26	.23
Cumulative variance	.26	.49
Proportion explained	.53	.47

Figure S1. ***Cross sectional path analysis of NEG on negative-high arousal emotion through internal attributions***

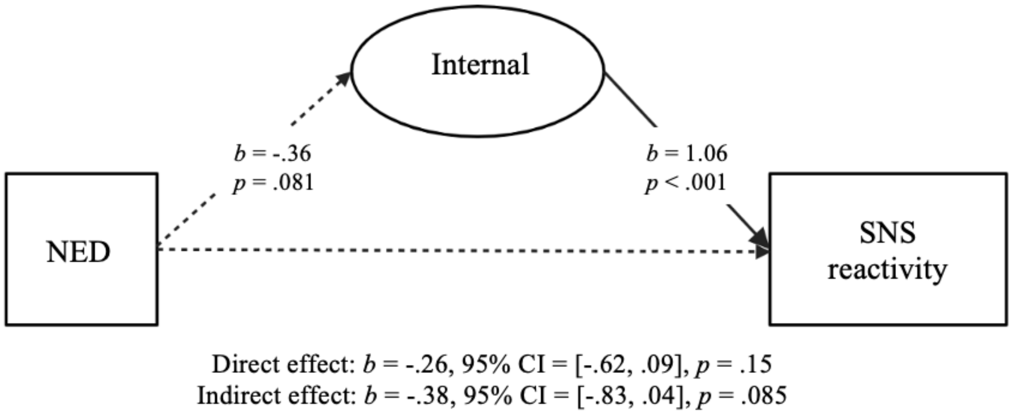


Fig. S1. Cross-sectional indirect effect of negative emotional differentiation on negative-high arousal emotion through internal attribution appraisals. Unstandardized coefficient estimates are reported in the main text. Unbroken arrows and broken arrows respectively represent significant and insignificant paths. $p < .05$. **, $p < .01$; key significant parameters in the mediation model are presented in boldface

Table S3. ***Regression results using SNS reactivity as the criterion and removing observations with large residuals***

Predictors	*b*	*b* [95% CI]	*β*	sr^2	sr^2 [95% CI]	Fit R^2 [95% CI]	Difference ΔR^2 [95% CI]
Step 1							
(Intercept)	0.40	[-0.02, 0.82]					
NED	0.41	[-0.01, 0.83]	0.14	.02	[-.02, .06]		
PED	0.22	[-0.16, 0.59]	0.08	.01	[-.02, .03]		
						R^2=.03* [.00, .08]	
Step 2							
(Intercept)	0.42	[-0.04, 0.89]					
NED	**0.52***	**[0.09, 0.95]**	**0.17**	**.03**	**[-.02, .07]**		
PED	0.25	[-0.15, 0.64]	0.09	.01	[-.02, .03]		
Mean neg affect	0.20	[-0.23, 0.62]	0.07	.00	[-.01, .02]		
Mean pos affect	-0.08	[-0.29, 0.13]	-0.06	.00	[-.01, .02]		
Sex	0.14	[-0.15, 0.42]	0.15	.00	[-.01, .02]		
Age	**0.15***	**[0.03, 0.26]**	**0.06**	**.03**	**[-.02, .08]**		
BMI	-0.03	[-0.08, 0.02]	0.02	.01	[-.02, .03]		
						R^2 =.08* [.01, .13]	ΔR^2 =.06 [-.01, .12]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. R^2 represents the unadjusted proportion of the variance for the criterion. * $p < .05$. **, $p < .01$.

Table S4. ***Exploratory regression results using negative high arousal emotion as the criterion and controlling for time elapsed between sessions***

Predictors	***b***	***b* [95% CI]**	***β***	***sr²***	***sr²* [95% CI]**	**Fit *R²* [95% CI]**	**Difference Δ*R²* [95% CI]**
Step 1							
(Intercept)	1.68**	[1.15, 2.22]					
NED	**-0.65***	**[-1.19, -0.12]**	**-.17**	**.03**	**[-.02, .08]**		
PED	-0.05	[-0.52, 0.43]	-.01	.00	[-.00, .00]		
						R^2 =.03 [.00, .08]	
Step 2							
(Intercept)	2.04**	[1.45, 2.62]					
NED	**-0.56***	**[-1.10, -0.02]**	**-0.15**	**.02**	**[-.02, .05]**		
PED	-0.03	[-0.52, 0.46]	0.01	.00	[-.00, .00]		
Mean neg affect	**0.67***	**[0.14, 1.19]**	**0.18**	**.03**	**[-.01, .07]**		
Mean pos affect	-0.09	[-0.34, 0.17]	-0.05	.00	[-.01, .01]		
Sex	**-0.65****	**[-1.00, -0.30]**	**-0.25**	**.06**	**[-.00, .12]**		
Age	-0.11	[-0.25, 0.03]	-.11	.01	[-.02, .04]		
Days elapsed between sessions	-0.00	[-0.00, 0.00]	-.04	.00	[-.01, .01]		
SNS reactivity	0.13	[-0.05, 0.30]	.10	.01	[-.02, .03]		
						R^2 =.14** [.03, .20]	ΔR^2 =.11** [.03, .19]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. R^2 represents the unadjusted proportion of the variance for the criterion. *$p < .05$, $p < .01$

Table S5. ***Exploratory regression results using SNS reactivity as the criterion and controlling for time elapsed between sessions***

Predictors	***b***	***b* [95% CI]**	**β**	**sr^2**	**sr^2 [95% CI]**	**Fit R^2 [95% CI]**	**Difference ΔR^2 [95% CI]**
Step 1							
(Intercept)	0.40	[-0.02, 0.82]					
NED	0.41	[-0.01, 0.83]	0.14	.02	[-.02, .06]		
PED	0.22	[-0.16, 0.59]	0.08	.01	[-.02, .03]		
						R^2=.03* [.00, .08]	
Step 2							
(Intercept)	0.44	[-0.04, 0.91]					
NED	**0.52***	**[0.09, 0.96]**	**0.17**	**.03**	**[-.02, .07]**		
PED	0.25	[-0.14, 0.65]	0.09	.01	[-.02, .03]		
Mean neg affect	0.20	[-0.23, 0.63]	0.07	.00	[-.01, .02]		
Mean pos affect	-0.08	[-0.29, 0.13]	-0.06	.00	[-.01, .02]		
Sex	0.14	[-0.15, 0.43]	0.15	.00	[-.01, .02]		
Age	**0.15****	**[0.04, 0.26]**	**0.06**	**.03**	**[-.01, .08]**		
BMI	-0.03	[-0.08, 0.02]	0.02	.01	[-.02, .03]		
Days elapsed between sessions	-0.00	[-0.00, 0.00]	0.00	.00	[-.01, .01]		
						R^2 =.08* [.01, .13]	ΔR^2 =.06 [-.01, .12]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. R^2 represents the unadjusted proportion of the variance for the criterion. * $p < .05$. **, $p < .01$.

Table S6. ***Exploratory regression results using HRV reactivity as the criterion***

Predictors	***b***	***b* [95% CI]**	**β**	***sr²***	***sr²* [95% CI]**	**Fit *R²* [95% CI]**	**Difference Δ*R²* [95% CI]**
Step 1							
(Intercept)	0.23	[-0.97, 1.42]					
NED	0.22	[-0.97, 1.42]	0.14	.00	[-.01, .01]		
PED	0.15	[-0.91, 1.20]	0.08	.00	[-.01, .01]		
						R^2=.001 [.00, .02]	
Step 2							
(Intercept)	0.47	[-0.80, 1.74]					
NED	0.92	[-0.27, 2.11]	0.11	.01	[-.02, .04]		
PED	0.06	[-1.01, 1.14]	0.01	.00	[-.00, .00]		
Mean neg affect	0.70	[-0.47, 1.86]	0.09	.01	[-.01, .03]		
Mean pos affect	-0.32	[-0.89, 0.25]	-0.08	.01	[-.01, .03]		
Sex	-0.09	[-0.88, 0.69]	-0.02	.00	[-.00, .00]		
Age	0.20	[-0.10, 0.51]	0.10	.01	[-.02, .03]		
BMI	-0.06	[-0.19, 0.07]	-0.06	.00	[-.01, .02]		
Heart rate	**-0.08****	**[-0.12, -0.05]**	**0.35**	**.12**	**[.03, .20]**		
						R^2 =.13* [.02, .19]	ΔR^2 =.06*** [.04, .22]

Note. For our chosen measure of HRV, we extracted the root mean square of successive differences between heartbeats (RMSSD), reflecting the beat-to-beat (R-to-R) variance in heart rate. To adjust RMSSD, we applied the formula found in de Geus et al. (2019), wherein a coefficient of variation or cvRMSSD = 100 * (RMSSD/IBI) with IBI being the interbeat interval or time in msbetween consecutive heartbeats. HRV herein refers to adujusted cvRMSSD measure. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. R^2 represents the unadjusted proportion of the variance for the criterion. * $p < .05$. **, $p < .01$.

Table S7. ***Exploratory regression results using negative high arousal emotion as the criterion and removing participants with negative ICC values***

Predictors	***b***	***b* [95% CI]**	***β***	***sr²***	***sr²* [95% CI]**	**Fit *R²* [95% CI]**	**Difference Δ*R²* [95% CI]**
Step 1							
(Intercept)	1.89**	[1.21, 2.57]					
NED	-0.52	[-1.17, 0.13]	-.12	.02	[-.02, .05]		
PED	0.05	[-0.52, 0.62]	-.01	.00	[-.00, .00]		
						R^2 =.02 [.00, .06]	
Step 2							
(Intercept)	2.37**	[1.63, 3.11]					
NED	-0.40	[-1.06, 0.26]	-0.10	.01	[-.02, .03]		
PED	0.19	[-0.39, 0.78]	0.05	.00	[-.01, .02]		
Mean neg affect	**0.83****	**[0.28, 1.39]**	**0.24**	**.05**	**[-.01, .11]**		
Mean pos affect	-0.08	[-0.37, 0.22]	-0.04	.00	[-.01, .01]		
Sex	**-0.64****	**[-1.03, -0.26]**	**-0.25**	**.06**	**[-.01, .13]**		
Age	-0.15	[-0.30, 0.00]	-.15	.02	[-.02, .06]		
SNS reactivity	0.04	[-0.17, 0.24]	.03	.00	[-.01, .01]		
						R^2 =.14** [.03, .21]	ΔR^2 =.13** [.03, .22]

Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. R^2 represents the unadjusted proportion of the variance for the criterion. *$p < .05$, $p < .01$

Table S8. ***Exploratory regression results using SNS reactivity as the criterion and removing participants with negative ICC values***

Predictors	***b***	***b* [95% CI]**	**β**	**sr^2**	**sr^2 [95% CI]**	**Fit R^2 [95% CI]**	**Difference ΔR^2 [95% CI]**
Step 1							
(Intercept)	0.51*	[0.00, 1.01]					
NED	**0.59***	**[0.11, 1.07]**	**0.19**	**.03**	**[-.02, .09]**		
PED	0.21	[-0.22, 0.63]	0.07	.01	[-.02, .03]		
						R^2=.04* [.00, .11]	
Step 2							
(Intercept)	0.55	[-0.02, 1.11]					
NED	**0.74****	**[0.24, 1.24]**	**0.23**	**.05**	**[-.01, .11]**		
PED	0.23	[-0.22, 0.68]	0.08	.01	[-.02, .03]		
Mean neg affect	0.27	[-0.16, 0.69]	0.10	.01	[-.02, .04]		
Mean pos affect	-0.08	[-0.31, 0.15]	-0.06	.00	[-.01, .02]		
Sex	0.16	[-0.13, 0.46]	0.08	.01	[-.02, .03]		
Age	**0.13***	**[0.01, 0.25]**	**0.17**	**.03**	**[-.02, .07]**		
BMI	-0.03	[-0.08, 0.02]	-.09	.01	[-.02, .03]		
						R^2 =.10* [.00, .15]	ΔR^2 =.06 [-.01, .12]

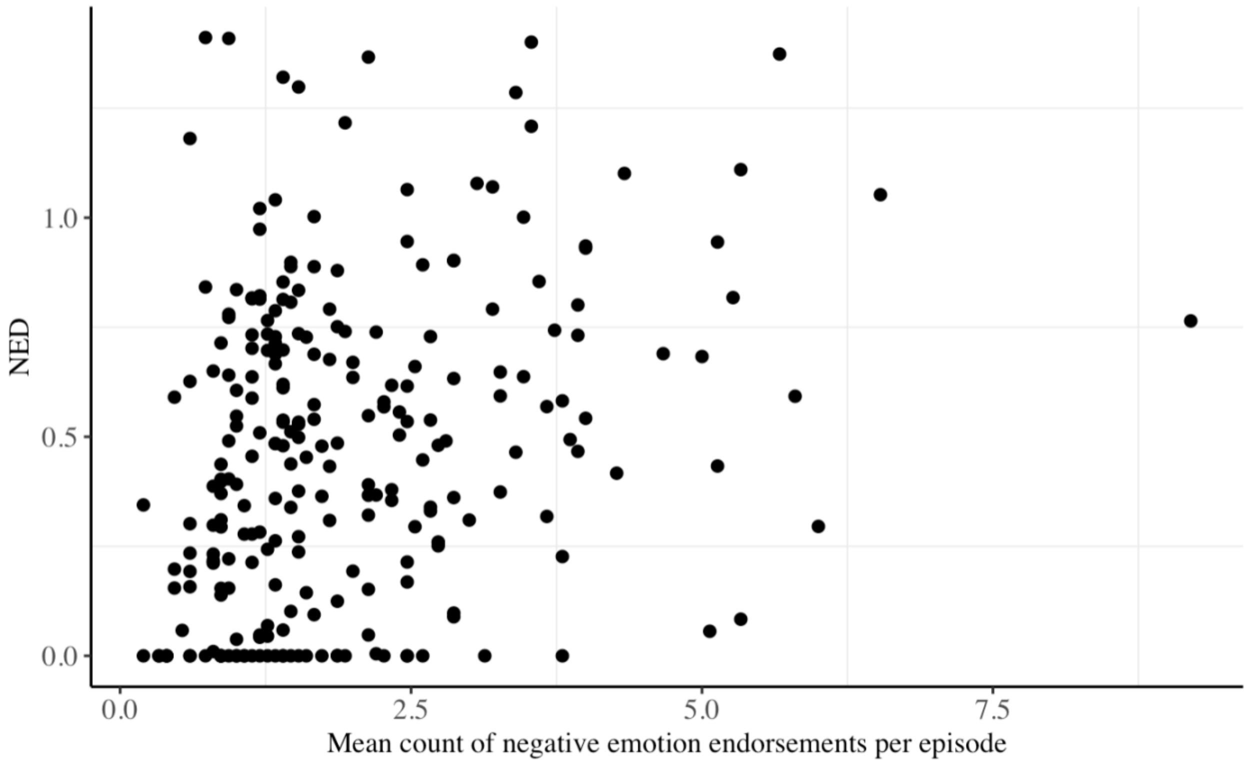
Note. A significant *b*-weight indicates the beta-weight and semi-partial correlation are also significant. *b* represents unstandardized regression weights. *b* indicates the standardized regression weights. sr^2 represents the semi-partial correlation squared. *r* represents the zero-order correlation. R^2 represents the unadjusted proportion of the variance for the criterion. * $p < .05$. **, $p < .01$.

Table 9 ***t-test results comparing participants with negative ICC values and participants with positive ICC values on average negative emotion endorsements***

Group	***n***	***Mean***	***t***	***df***	**95% CI**	**Cohen's d**
Positive ICC value	213	2.07	4.60**	70.21	[.43, 1.09]	.69
Negative ICC value	37	1.21				

***$p < .001$

Figure S2. ***Relationship between average number of negative emotions endorsed on the Day Reconstruction Method and NED***



Supplementary References

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