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Evidence for differential associations of distinct trait mindfulness facets with acute and chronic stress

Mathilde Gallistl [a,*], Roman Linz [a], Lara M.C. Puhlmann [a,c], Tania Singer [d,1], Veronika Engert [a,b,e,1]

[a] Independent Research Group "Social Stress and Family Health", Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany
[b] Institute for Psychosocial Medicine, Psychotherapy and Psychooncology, Jena University Hospital, Friedrich-Schiller University, Jena, Germany
[c] Leibniz Institute for Resilience Research (LIR), Mainz, Germany
[d] Social Neuroscience Lab, Max Planck Society, Berlin, Germany
[e] German Center for Mental Health (DZPG), partner site Halle-Jena-Magdeburg

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ABSTRACT

Stress and stress-associated disease are considered the health epidemic of the 21st century. Interestingly, despite experiencing similar amounts of stress than those falling ill, some individuals are protected against the "wear and tear of daily life". Based on the notion that mindfulness training strengthens stress resilience, we explored whether facets of trait mindfulness, prior to training intervention, are linked to acute psychosocial stress reactivity and chronic stress load. To assess different mindfulness facets, over 130 participants completed the Five Facet Mindfulness Questionnaire (FFMQ) and the Freiburg Mindfulness Inventory (FMI). For acute stress induction, a standardized psychosocial stress test was conducted. Subjective stress, sympathetic and parasympathetic activity, and levels of the hypothalamic-pituitary-adrenal axis end hormone cortisol were assessed repeatedly. Additionally, levels of hair cortisol and cortisone as indices of the long-term physiological stress load were collected. We found differential associations of different facets of mindfulness with subjective stress, cortisol, and hair cortisone levels. Specifically, the trait mindfulness facets FMI "Acceptance" and the ability to put one's inner experience into words (FFMQ "Describing") were associated with lower acute subjective and cortisol stress reactivity. Contrarily, monitoring-related trait mindfulness facets (FFMQ "Acting with Awareness" and "Observing") were associated with higher acute cortisol and marginally higher long-term cortisone release. Our results suggest granularity of the mindfulness construct. In accordance with the "Monitor and Acceptance Theory", especially acceptance-related traits buffered against stress, while monitoring-related traits seemed to be maladaptive in the context of stress. The current results give valuable guidance for the conceptualization of mindfulness-based interventions geared towards stress reduction.

1. Introduction

Stress is known to everyone, and often experienced daily. Yet, how people respond to it is highly diverse. While some develop stress-associated disease (Chrousos, 2009), others thrive despite high exposure (Galatzer-Levy et al., 2018). Mindfulness training is a popular means to reduce the subjective and physiological stress burden (Querstret et al., 2020). We here investigate how different trait mindfulness facets predict emotional and physiological stress sensitivity prior to engagement in mental training interventions. Because stress is a complex construct (Engert et al., 2018), and acute reactivity not always reflects the chronic stress load (Degering et al., 2023), we focus on different stress markers and states of stress.

The stress response involves interdependent psychological and physiological processes following a threat to homeostasis (Chrousos, 2009). Physiologically, the core stress systems are the sympathetic-adrenal-medullary system and the hypothalamic–pituitary–adrenal (HPA) axis which secretes the main stress

* Correspondence to: Independent Research Group "Social Stress and Family Health", Max Planck Institute for Human Cognitive and Brain Sciences, Stephanstraße 1A, Leipzig 04103, Germany
E-mail address: gallistl@cbs.mpg.de (M. Gallistl).
[1] joint last authors

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hormone cortisol. Acute stress is essential to overcome life-threatening situations by providing energy for the "fight-or-flight" response (Cannon, 1915). However, chronic stress may lead to health deterioration (Chrousos, 2009), including depression, cardiovascular, metabolic and autoimmune disease (Cohen et al., 2007). As humans, we are particularly vulnerable to chronic stress because we activate the stress systems also for psychosocial stressors, circumstances that can feel uncontrollable, novel, or ego-threatening (Dickerson and Kemeny, 2004; Sapolsky, 2004). Mindfulness, defined as "purposely bringing one's attention to the present moment without evaluation" (Kabat-Zinn, 2005), can be trained to buffer stress sensitivity (Querstret et al., 2020), suggesting a role of trait mindfulness as a resilience factor already at baseline. Scientific evidence on how trait mindfulness relates to stress sensitivity is limited and mixed.

Higher self-reported trait mindfulness was found to predict lower acute stress reactivity in a standardized psychosocial laboratory stressor, with stress measured through self-report (specifically the facet "Describing" of the Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006)) (e.g. Brown et al., 2012; Lin et al., 2020; Lucas-Thompson et al., 2019), sympathetic arousal (specifically the FFMQ facet "Non--judging") (Beshai et al., 2020; Lucas-Thompson et al., 2019), and cortisol release (Brown et al., 2012; Lin et al., 2020). However, higher trait mindfulness has also been shown to be linked to increased heart rate (FFMQ facet "Non-reacting"; Beshai et al., 2020), and cortisol reactivity (Lucas-Thompson et al., 2019) following acute psychosocial stress. The authors of the FFMQ define the facet "Describing" as the ability to put one's experiences and emotions into words, the facet "Non-judging" as the inclination of not evaluating an internal experience as good or bad, and the facet "Non-reacting" as the tendency to abstain from promptly reacting to an internal experience (Baer et al., 2006).

One study by Manigault et al. (2018) particularly stands out: Despite finding trait mindfulness to be associated with *greater* odds of displaying a cortisol response to acute psychosocial stress, the authors suggest that mindfulness is adaptive. Their interpretation is based on the rationale that showing a reduced stress response in the face of challenge would leave the individual unequipped to adequately cope with the challenge. This is true in situations requiring fight-or-flight reactions to survive. Similarly, the argument can be made for depressed patients with blunted HPA axis reactivity despite high levels of subjective stress (Burke et al., 2005). Given psychosocial stressors which are the predominant cause of chronic stress in modern societies (Sapolsky, 2015), *not* feeling stressed in the first place seems like the most adaptive response. Heightened stress responses contrarily would be considered a risk factor.

We aimed to unravel this inconsistency in the link between trait mindfulness and stress sensitivity by addressing three questions. First, whether mixed previous findings may be explained by the fact that mindfulness is a multifaceted construct (Lindsay and Creswell, 2017). Second, whether different stress markers (subjective arousal, autonomic activity, cortisol release) differed in their link to trait mindfulness. Third, whether increased rather than decreased acute psychosocial stress reactivity could be interpreted as indicator of adaptive stress responding.

We used the baseline data of a longitudinal mental training study, the *ReSource Project* (Singer et al., 2016), to examine associations of trait mindfulness facets with acute psychosocial stress reactivity and chronic stress load. Trait mindfulness was assessed using two questionnaires chosen from a larger pool of self-report instruments (Singer et al., 2016), the FFMQ and the Freiburg Mindfulness Inventory (FMI; Buchheld et al., 2001; Walach et al., 2006). Psychosocial stress was induced with the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). Subjective, autonomic and cortisol responses were analyzed during stress reactivity. These data have been previously published in the context of various research questions and combined with diverse other variables assessed in the *ReSource Project* (see Supplementary Material for a list of all papers). Hair cortisol and cortisone concentrations, indicative of the long-term physiological stress load, were also collected (see Supplementary Material for prior papers using these data). They capture systemic cortisol exposure, and are linked to subjective stress and stress-associated disease (Stalder et al., 2017). Relating acute stress reactivity to the long-term stress load allowed to determine the (non-) adaptivity of heightened acute stress reactivity. If, indeed, increased stress reactivity in individuals with higher mindfulness is adaptive, it should be coupled with lower levels of, undoubtedly maladaptive, long-term stress.

We expected opposite associations of different trait mindfulness facets with stress reactivity. Recent research suggests FFMQ "Non-reacting" to predict higher, and "Describing" and "Non-judging" to predict lower responses to acute psychosocial stress (Beshai et al., 2020; Lin et al., 2020). A prominent theory developed to dismantle the components of mindfulness training, the "Monitor and Acceptance Theory" (MAT; Lindsay and Creswell, 2017, 2019), suggests that mindfulness training reduces stress by improving attentional (i.e., monitoring) and emotional (i.e., acceptance) skills. Because better monitoring abilities enhance attentional salience to positive *and* negative internal states, initial symptom exacerbation may occur. With acceptance cultivation, individuals are suggested to gradually learn how to handle their amplified receptivity to internal signals. Only then, stress reduction can take place. Accordingly, monitoring facets, such as "Observing" (FFMQ) and "Presence" (FMI) should be associated with higher stress reactivity. The notion that "Observing" may be maladaptive and associated with a variety of mental health symptoms has received considerable attention also outside the MAT (Burzler and Tran, 2022). Acceptance facets, such as "Non-reacting", "Non-judging" (both FFMQ) and "Acceptance" (FMI) should conversely be linked to reduced stress reactivity (Lindsay and Creswell, 2017, 2019). Last, we expected mindfulness facets linked to higher acute reactivity to also be associated with higher long-term stress load. Whether specific markers or states of stress would differentially relate to trait mindfulness was examined in an exploratory analysis. All results reported in this paper are based on a secondary data analysis which has not been preregistered.

2. Material and methods

2.1. Participants

Participants were recruited in the context of the *ReSource Project*, a multi-method longitudinal mental training intervention conducted between 2013 and 2016 at the Department of Social Neuroscience of the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig and Berlin, Germany (Singer et al., 2016). The project aimed to differentially investigate the effects of distinct types of mental training on a broad range of behavior, subjective, brain and peripheral physiological biomarkers (for a review see Singer and Engert, 2019). Therefore, participants provided measures at different time points before (at T0) and during up to nine-months of mental training (at T1, T2, and T3). Out of the 332 *ReSource* participants, a subsample of N=131 (78 women; age M = 40.00, SD = 9.28, age range = 20–55) was subjected to the Trier Social Stress Test *without prior training exposure* (either at T0, or as part of a retest control cohort, at T1 or T2, and therefore included in the current analysis). Hair cortisol levels were taken at T0 for 229 participants (160 women; age M = 40.00, SD = 9.38, age range = 20–55).

Before study onset, volunteers underwent a comprehensive face-to-face mental health diagnostic interview with a trained clinical psychologist. The interview included a computer-assisted German version of the Structured Clinical Interview for DSM-IV Axis-I disorders, the SCID-I DIA-X Wittchen and Pfister, (1997), and a personal interview for Axis-II disorders, the SCID-II (Wittchen et al., 1997). Volunteers were excluded if they fulfilled criteria for an Axis-I disorder, including psychotic disorder, bipolar disorder, and substance dependency, within the past two years, an Axis-II disorder at any time in their life, or were taking medication influencing the HPA axis. More details on inclusion and exclusion criteria can be found in Singer et al. (2016). At the testing time point reported here, all participants were training-naïve. Female hormonal status on the day of stress testing was assessed through self-report; 36 women had a natural menstrual cycle, 16 were on hormonal contraceptives, and 25 had no cycle due to menopause or polycystic ovary syndrome.

The *ReSource Project* was registered with the Protocol Registration System of ClinicalTrial.gov under the title "Plasticity of the Compassionate Brain" (Identifier NCT01833104). It was approved by the Research Ethics Boards of Leipzig University (ethics number: 376/12-ff) and Humboldt University Berlin (ethics number: 2013–20, 2013–29, 2014–10). Participants gave their written informed consent, could withdraw from the study at any time, and were financially compensated.

Although the data reported here have previously been published in the context of other research questions (baseline testing time point: e.g., Degering et al., 2023; Engert et al., 2018; post-training: Engert et al., 2017; Puhlmann et al., 2021; see Supplementary Material for a complete list) none of these studies examined the link between self-reported trait mindfulness and markers of stress reactivity. The current study is an a-posteriori exploratory study not planned in the conceptual phase and designing of the *ReSource Project*. Therefore, the sample sizes were not tailored to this study.

2.2. Experimental design

Participants underwent the TSST at different time points, between T0 and T2; all of them were training-naïve at the time of testing. Trait questionnaires were collected within the 5 weeks before and after the stress testing session. The TSST was performed in one 130-min session. Because cortisol secretion follows a circadian rhythm (Fries et al., 2009), all participants were tested between 12 pm and 6 pm to minimize differences in baseline cortisol levels. Participants were instructed to refrain from consuming coffee one hour prior to the experiment, from alcohol the evening prior, and from smoking on the day of testing. Participants arrived at the laboratory at −70 min relative to stressor onset, and had a small snack to adjust blood sugar levels. For the remainder of the session, they did not eat or drink anything except water. At −55 min, participants provided the first saliva and questionnaire samples to gauge cortisol and self-reported stress at baseline. At −50 min, a blood sample was drawn to capture immune reactivity, which was not evaluated in the current analysis. After a 30-min resting phase to overcome potential stress induced by the blood draw, participants received TSST instructions (-15 min). Following 10 min of stress anticipation, self-reported stress was assessed at −5 min, amounting to a 15 min anticipation phase overall, followed by the 10 min stress phase. Immediately after the TSST, self-reported stress was assessed again, and a second blood sample was collected at between 10 and 15 min. In a subsequent 60-min recovery phase, repeated saliva and questionnaire samples were collected. A continuous electrocardiogram (ECG) was measured for 55 min from −30 to 25 min. At the end of the recovery phase, a final blood sample was drawn. The testing timeline is shown in Fig. 1. Hair samples for cortisol and cortisone analysis were collected at T0, before any training intervention took place, for all participants of the *ReSource* study. Consequently, hair cortisol and cortisone analyses comprise a larger sample than analysis of acute stress data.

2.3. Trait questionnaires

2.3.1 Five-Facet Mindfulness Questionnaire. The Five-Facet Mindfulness Questionnaire was constructed from a factor analysis of five different mindfulness scales (FFMQ; Baer et al., 2006). It assesses five facets of mindfulness: Non-reacting to inner experiences (ability to not react to inner experiences; let feelings and thoughts come and go), Observing (ability to attend to and notice external and internal experiences, e.g. sensations, cognitions and emotions), Acting with Awareness (ability to pay attention to an ongoing activity, in contrast to being in "auto-pilot mode"), Describing (ability to accurately put feelings, thoughts or experiences into words), and Non-judging of experience (ability to not judge and take a non-evaluative attitude to inner experiences). The validity and reliability of each facet is acceptable (Christopher et al., 2012).

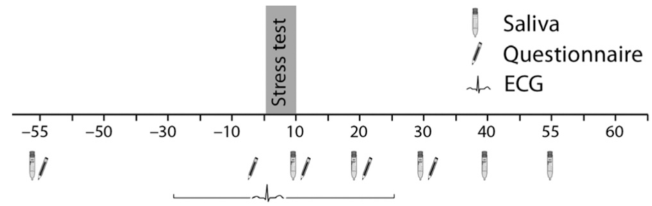

Fig. 1. Stress testing timeline and assessed measures over time. At −55 min (relative to stressor onset at 0 min), participants provided the first saliva and questionnaire samples to gauge cortisol and self-reported stress at baseline. After a 30 -min resting phase, TSST instructions were given (-15 min). Following 10 min of stress anticipation, self-reported stress was assessed at −5 min, followed by the 10 min stress phase. Immediately after the TSST, self-reported stress was assessed at 10 min. In a subsequent 60-min recovery phase, repeated questionnaire and saliva samples were collected (at 20 and 30, and at 20, 30, 40 and 55 min, respectively). A continuous electrocardiogram (ECG) was measured during altogether 55 min from −30–25 min. ECG: electrocardiogram. Figure adapted from Engert et al. (2017).

2.3.2 Freiburg Mindfulness Inventory – short version. The Freiburg Mindfulness Inventory (FMI; Buchheld et al., 2001; Walach et al., 2006) was constructed on the basis of reports of experienced meditators, and captures two facets of mindfulness: Presence (attending to the present moment) and Acceptance (openness to negative experience). Good reliability and validity have been shown (Leigh et al., 2005). It has been tested in and shortened for non-meditators (Kohls et al., 2009).

2.4. Stress induction

The Trier Social Stress Test (TSST; Kirschbaum et al., 1993) was administered for acute stress induction. It is a standardized social-evaluative laboratory stressor in form of a mock job-interview, and reliably elicits subjective and physiological stress responses (Kudielka et al., 2007). Compared to numerous alternative laboratory stressors, it provokes the most robust HPA axis activation (Dickerson and Kemeny, 2004). In detail, after a stress anticipation phase of variable duration (15 min in the current study), participants are instructed to give a 5 min free speech, followed by a 5 min mental arithmetic task. While being audio- and video-taped, participants have to perform in front of a committee of two allegedly trained behavioral psychologists, whom they believe evaluate their verbal and non-verbal behavior, and general quality of performance.

2.5. Stress markers

2.5.1. Subjective stress experience

Subjective stress experience was assessed with the state scale of the State Trait Anxiety Inventory (STAI; Spielberger et al., 1970), the most frequently used instrument to measure stress-induced subjective-emotional states (Campbell and Ehlert, 2012). It is a 20-items instrument measuring acute feelings of tension, worry, nervousness, and arousal. In our study, it was completed five times throughout the testing session. Relative to stressor onset (at 0 min), sampling took place at −55 min (baseline), −5 min (after stress anticipation), and at 10, 20, and 30 min (after stressor termination).

2.5.2. Salivary cortisol

Cortisol is a primary biomarker of the human stress response (Hellhammer et al., 2009) and was measured from saliva using Salivette collection devices (Sarstedt, Nümbrecht, Germany). Since cortisol follows a circadian rhythm with highest levels after awakening, testing was performed in the afternoon. Relative to stressor onset (at 0 min), sampling took place at −55 min (baseline), and at 10, 20, 30, 40, and 55 min after stressor termination. Participants placed a Salivette collection swab in their mouth for 2 min and refrained from chewing. To ensure that samples were not contaminated with external particles, participants did not to eat or drink anything other than water during the sampling period. Salivettes were stored at −30°C until analysis. Cortisol levels were analyzed (at the biochemical laboratory of the Department of Biological and Clinical Psychology, Trier University, Germany) using a time-resolved fluorescence immunoassay with intra-/interassay variabilities of <10%/12% (Dressendörfer et al., 1992).

2.5.3. Cardiovascular measures

Heart rate (HR) and high frequency heart rate variability (HF-HRV) are markers of the autonomous nervous system, and were assessed with a continuous electrocardiogram (ECG) using the Zephyr Bioharness 3 (Zephyr Technology, Annapolis, Maryland, USA). This device is designed as a chest belt, and samples at a frequency of 250 Hz. Cardiovascular measures were assessed for 55 min, from −30 to +25 min relative to TSST onset at 0 min, covering a 10 min baseline phase (from −30 to −20 min), 20 min of stress anticipation (from −20 to 0 min), 10 min of acute stress (from 0 to 10 min), and a 15 min recovery phase (10–25 min). Because of interindividual differences in the transition between phases, only the mid 8 min sequences of baseline and stress phases were included into the analysis. For the recovery phase, only the final 8 min were included due to variable length of the preceding blood draw. The anticipation phase was dropped from analysis altogether because no equivalent anticipation sample for cortisol was collected. Cardiovascular TSST data was processed and analyzed in this manner consistently throughout all *ReSource* publications (see Supplementary Material).

ECGs were extracted using the software Matrix Laboratory (Matlab; version R2014a). Subsequently, they were automatically checked for artifacts using in-house software, and additionally corrected manually for remaining artifacts. For every 8 min time frame of each experimental phase (baseline, stress, recovery), average HR (in beats/min) and HF-HRV (in millisec^2) was calculated using the software ARTiiFACT (version 2) (Kaufmann et al., 2011).

2.5.4. Hair cortisol and cortisone

Hair cortisol and hair cortisone concentrations indicate chronic stress (Stalder et al., 2017). Levels of the inactive cortisol metabolite and precursor molecule cortisone have been suggested to yield a complementary, potentially more stable glucocorticoid signal alongside cortisol itself (Stalder et al., 2013; Supplementary Material). Free hair cortisol/cortisone molecules are assumed to accumulate in the hair follicles proportionally to their overall concentration in the body while hair is growing. Assuming a hair growth rate of on average 1 cm/month (Wennig, 2000), we analyzed 3 cm hair segments to assess accumulation over three months. Hair strands were taken as close as possible to the scalp from a posterior vertex position. Until assay (at the biochemical laboratory of the Department of Biopsychology, Dresden University of Technology, Germany), they were wrapped in aluminum foil, and stored at room temperature. Liquid chromatography-tandem mass spectrometry (LC–MS/MS) was used to measure hormone concentrations, which is the current gold-standard approach for hair steroid analysis (Gao et al., 2016). Following a previously published protocol (Gao et al., 2013), a limit of quantification for cortisol and cortisone below 0.09 pg/mg, and intra- and inter-assay CVs between 3.7% and 8.8% were set.

2.6. Statistical analysis

2.6.1. Data preparation

All analyses were conducted using R, version 4.0.2 (R Core Team, 2020). Due to skewness, physiological data was ln-transformed to approach normal distribution. Outliers were winsorized to 3 *SDs* from the mean. Continuous predictors were z-transformed and mean-centered in linear models to facilitate interpretation. Significance was set at $p \leq .05$, all tests were two-sided, and a Bonferroni correction was applied to account for multiple tests within conceptual clusters ($p \leq .025$ for HR and HF-HRV; $p \leq .025$ for hair cortisol and cortisone).

2.6.2. Main analyses

Associations of trait mindfulness and stress sensitivity were analyzed in terms of acute (assessed via subjective stress, cortisol, HR, and HF-HRV), and chronic response levels (assessed via hair cortisol and cortisone levels). As control variables, age, hormonal status (Kajantie and Phillips, 2006), and time of day (in min after 12 pm) (Kirschbaum and Hellhammer, 1989) were included into the acute stress salivary cortisol model given their influence on HPA axis activity. Age and sex were included into the hair cortisol and cortisone models to account for potential influences on hormone concentrations (Stalder et al., 2017), as was done in our previous publication using some of the same data (Puhlmann et al., 2021). Models concerned with sympathetic and parasympathetic regulation included sex, age, and BMI as controlling factors (Ferrucci et al., 1999; Ledue and Rifai, 2003; Thayer et al., 2010). Age was included as control variable into all models given the considerable age range of our sample (20–55 years), and for consistency reasons with earlier *ReSource* publications.

Acute stress. For subjective-psychological stress, cortisol, HR, and HF-HRV, four Linear Mixed Models (LMMs) were calculated using the packages lme4 and car (Fox and Weisberg, 2019). In each model, repeated measures of a respective stress marker were nested within individuals, allowing for a random intercept per participant. Due to a lack of variance, no random slope was specified. We only included data gauging stress reactivity, that is, samples from baseline to the average stress peak. Across all participants, average stress peaks occurred at −5 min for subjective stress, during the stress phase between 0 and 10 min for autonomous markers, and at 20 min for cortisol. Further, for each model, all subscales of FFMQ (Describing, Observing, Acting with Awareness, Non-judging, Non-reacting) and FMI (Presence, Acceptance), their two-way interactions with time (min relative to TSST onset), and the respective control factors were included as level 2 predictors. Multicollinearity was calculated using the vif function of the car package.

Because the FMI is partially embedded in the FFMQ questionnaire and the FMI scale "Presence" has low reliability in non-meditators, we reran the above described analyses using only the FFMQ subscales (see Supplementary Material for full results). For reasons of consistency with earlier papers from the *ReSource Project* (see Supplementary Material for the full list) the current main analysis included both questionnaires.

Chronic stress exposure. Linear Models were calculated testing the association of the FFMQ and FMI subscales with hair cortisol (1) and cortisone levels (2), using age and sex as covariates. Again, models including only the FFMQ subscales are shown in the Supplementary Material.

3. Results

3.1. Preliminary analysis

3.1.1. Descriptive statistics

The acute stress sample consisted of 136 participants (78 women) with a mean age of 40.00±9.28 years. Hair sampling was realized in 229 participants (160 women) with a mean age of 40.00±9.38 years. Means and standard deviation of each trait mindfulness facet are displayed in Table 1. Mean distribution of acute cortisol reactivity within our sample is depicted in Fig. 2.

Table 1
Descriptive Statistics for the acute and chronic stress sample, providing mean and standard deviation for each independent variable. FFMQ: Five Facet Mindfulness Questionnaire (Baer et al., 2006), FMI: Freiburg Mindfulness Inventory (Buchheld et al., 2001; Walach et al., 2006).

	Acute stress sample *mean (SD)*	Chronic stress sample *mean (SD)*
FFMQ Describing	28.54 (5.66)	28.26 (5.74)
FFMQ Observing	26.81 (5.04)	27.01 (4.86)
FFMQ Non-judging	32.22 (5.51)	32.01 (5.69)
FFMQ Non-reacting	21.47 (4.66)	21.06 (4.57)
FFMQ Acting with Awareness	27.54 (5.07)	27.56 (5.08)
FMI Acceptance	1.70 (0.41)	1.64 (0.04)
FMI Presence	1.71 (0.49)	1.65 (0.49)
Age (years)	40.00 (9.28)	40.00 (9.38)
N	136 [78 women]	229 [160 women]

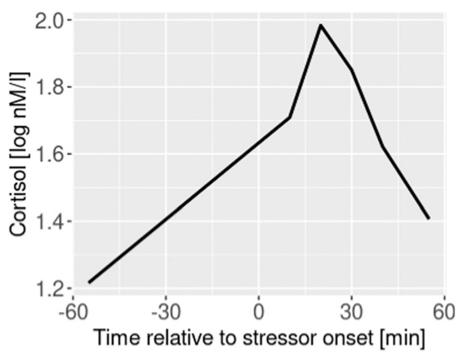

Fig. 2. Acute cortisol data. Distribution of mean salivary cortisol within the acute stress sample relative to stressor onset at 0 mins.

3.1.2. *Verification of successful stress induction*

The effectiveness of the TSST to activate the HPA axis was verified. A physiologically significant stress response has been identified as an increase in cortisol of 1.5 nmol/l above baseline levels (Miller et al., 2013). In the present sample, the TSST triggered cortisol release at or above this threshold in 75% of participants, thus indicating successful stress induction.

3.2. *Main analysis*

3.2.1. *Acute stress reactivity*

Subjective stress. Next to a main effect of time (b=0.27, t(128.2)= 17.91, p<.001), there was a significant main effect of the FMI "Acceptance" scale (b=-2.9, t(241.7)=-3.14, p=.002) and an interaction of time and FMI Acceptance (b=-0.04, t(128.3)=-2.15, p=.03; Fig. 3C), indicating lower subjective stress reactivity in individuals with higher FMI "Acceptance". None of the remaining questionnaire subscales showed significant associations with subjective stress reactivity (Table 2).

Autonomic activity. There was a time main effect in both heart rate and high frequency heart rate variability (HR: b=0.01, t(215.4)=17.87, p<.001; HF-HRV: b=-0.02, t(215.7)=4.02, p<.001). Further, age had a significant effect on high frequency heart rate variability (b=0.45, t(109.7)=-3.60, p<.001). None of the questionnaire subscales were associated with either heart rate or high frequency heart rate variability (Table 2).

Cortisol activity. Again, there was a significant main effect of time (b=0.01, t(256.7)=15.02, p<.001) on cortisol activity. Also, age (b=-0.10, t(130.5)=-2.22, p=.03), time of day (b=-0.002, t(130.1)=-4.07, p<.001), and hormonal status (b=-0.17, t(130.4)=-3.27, p=.001) were linked to cortisol activity (Table 2). Regarding different facets of mindfulness, there was a significant main effect of the FFMQ "Describing" scale (b=-0.10, t(134.2)=-2.08, p=.04) and a significant interaction of time and "Describing" (b=-0.002, t(256.9)=-3.42, p<.001; Fig. 3A), such that higher describing abilities were associated with lower cortisol stress reactivity. Further, we found a significant interaction of time and the FFMQ "Acting with Awareness" scale (b=0.002 t(267.4)= 2.00, p=.046; Fig. 3B), indicating higher stress reactivity with higher levels of "Acting with Awareness". None of the remaining questionnaire subscales showed any association with salivary cortisol levels (Table 2). Multicollinearity was below 5 for all models.

3.2.2. *Chronic stress*

Regarding hair cortisol and cortisone, there was an effect of sex on hair cortisone (R^2=0.09, b=0.31, t=-2.80, p=.006). Further, there was a main effect of the FFMQ facet "Observing" on hair cortisone levels (R^2=0.09, b=0.14, t=2.16, p=.03), indicating that higher scores in the observing facet were linked to higher hair cortisone concentrations (Table 3). After Bonferroni correction ($p\leq$.05/2), this result was only marginally significant. Again, multicollinearity was below 5 for both models. For all analysis, standardized effect sizes and estimates with a digit shift (times 100) are shown in the Supplementary Material.

4. Discussion

Many people suffer from stress and the development of stress-associated disease. Mindfulness training is popular and effective in reducing stress. The current study aimed to unravel the link between different trait mindfulness facets, assessed prior to engagement in mental training interventions, and stress sensitivity, employing different physiological markers of acute psychosocial and chronic stress.

In detail, we examined associations of different facets of trait mindfulness [measured using the Five Factor Mindfulness Questionnaire (FFMQ; Baer et al., 2006) and the Freiburg Mindfulness Inventory (FMI; Buchheld et al., 2001; Walach et al., 2006)] with acute psychosocial stress reactivity and the chronic stress load. Acute reactivity was captured in terms of subjective-psychological, sympathetic, parasympathetic and HPA axis activation; the chronic stress load in terms of cortisol and cortisone accumulation in hair. Considering both, acute reactivity and the long-term stress load, allowed to draw conclusions about whether an association of trait mindfulness with heightened acute stress reactivity after psychosocial stress induction is adaptive in healthy individuals, as suggested in a publication by Manigault et al. (2018), or contrariwise, rather an expression of heightened stress sensitivity.

Our analyses revealed that several facets of trait mindfulness were linked to reduced levels of acute psychosocial stress. Thus, higher scores in FMI "Acceptance" were associated with lower subjective stress reactivity, and higher scores in FFMQ "Describing" with lower cortisol reactivity. The FFMQ scale "Acting with Awareness" contrarily showed a link with higher cortisol reactivity. On the chronic stress level, the FFMQ "Observing" scale showed a positive (albeit marginal) association with hair cortisone concentrations, such that a higher ability to observe inner experiences came with a relatively increased chronic stress load.

These results extend prior findings of reduced subjective responses to psychosocial stress in participants with higher levels of trait "Describing" (Lin et al., 2020). Moreover, the overall result pattern sheds light on several important theoretical considerations. First, the fact that different facets of mindfulness had an opposite relationship with stress sensitivity confirms the idea that mindfulness is a complex and granular construct, subsuming distinct dimensions. Mindfulness training studies, which often aim specifically towards a reduction in stress sensitivity, should bear this granularity in mind when designing interventions and defining training goals. On that note, we recently emphasized the need for more granularity in meditation-based mental training interventions. We suggested that practice type matters, and that the umbrella concepts of mindfulness or meditation-based interventions need further differentiation in order to properly disclose which kinds of mental training lead to which outcomes (Singer and Engert, 2019).

Second, we found that different stress markers seem to have differential associations with distinct facets of mindfulness. Thus, while levels

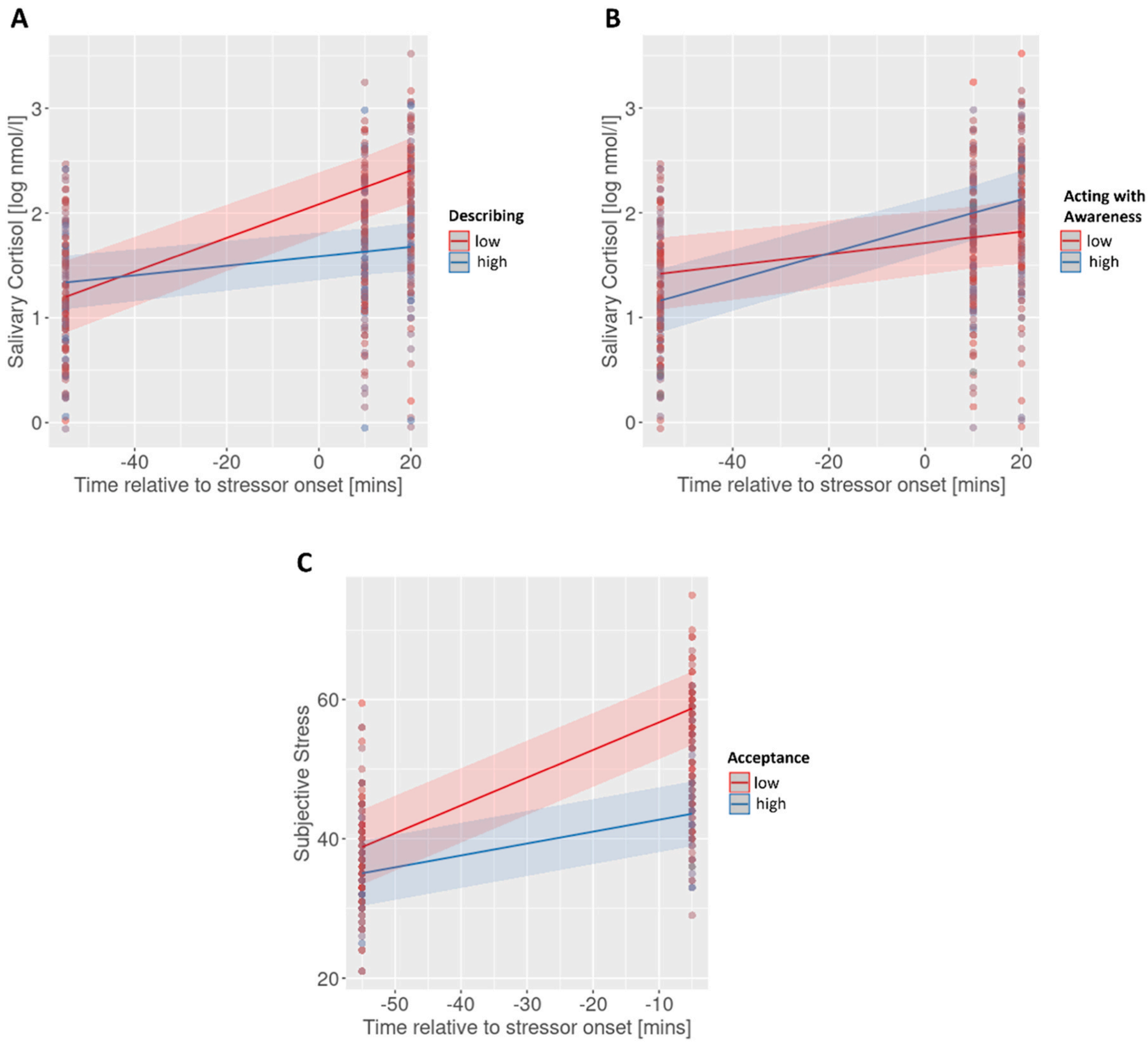

Fig. 3. Association of Describing and Acting with Awareness with salivary cortisol, and Acceptance with subjective stress. Linear Mixed Models revealed that A) higher Describing correlated with lower salivary cortisol reactivity (t=-3.42, p<.001) B) higher Acting with Awareness correlated with higher salivary cortisol reactivity (t=2.00, p=.046) C) higher Acceptance correlated with lower subjective stress reactivity (t=-2.15, p=.03).

of subjective stress assessed with the State Trait Anxiety Inventory (STAI; Spielberger et al., 1970) and cortisol (assessed both in saliva and hair) were repeatedly linked to facets of trait mindfulness, autonomic markers, such as heart rate and HF-HRV, showed no association. We suggest the discrepancy in HPA axis and autonomic findings may reflect underlying differences in the reactivity of these stress response systems. Thus, HPA axis activity is specific to distress and strongly influenced by internal evaluations (Dickerson and Kemeny, 2004). Autonomic activity, on the other hand, is a correlate of moment-to-moment arousal, equally responding to positively- and negatively-valenced stimuli (Kreibig, 2010), and may therefore be less sensitive to individual differences in mindfulness capacities.

Third, referring to the study by Manigault et al. (2018), our results allow to cautiously challenge their suggestion that in a healthy sample, relatively increased acute psychosocial stress reactivity in individuals with higher mindfulness abilities is adaptive. Although the FFMQ "Observing" facet showed only a marginal association with hair cortisone levels, and a direct link from increased acute psychosocial stress reactivity to an elevated chronic stress load can therefore not be made, this finding indicates that a generally adaptive capacity, namely the ability to attend to and notice external and internal experiences (Baer et al., 2006), may turn out to be maladaptive under stressful circumstances. This reasoning is also in line with previous mindfulness research (for a review see Burzler and Tran, 2022). While we make the argument here that what is maladaptive in the acute challenge situation is also maladaptive in everyday life, a different view is possible. Thus, "Acting with Awareness" and "Observing" could be a resource in the daily life context, particularly because perceiving stressed states more clearly may trigger the successful use of alternative coping strategies unavailable in the rigid laboratory context. Examples for such alternative strategies could be the seeking of social support or the avoidance of perceived stressors.

The finding that some facets of mindfulness may be, in fact, an obstacle to stress reduction, is also in line with the Monitor and Acceptance Theory (MAT; Lindsay and Creswell, 2017, 2019). While the MAT makes this assumption specifically in the context of mindfulness *training*, a stronger trait tendency for monitoring may amplify an individual's receptivity to their internal signals even without prior training. In stressful circumstances, a habitually amplified perception of negative arousal may lead to exacerbation and prolongation of stressed states, thus accumulating to a higher long-term stress load. Evidence for such initial symptom exacerbation in terms of cortisol stress reactivity after mental training is presented by the authors of the MAT (Creswell et al., 2014), as well as our own group (Engert et al., 2017, 2023). The MAT continues to postulate that gradually, by means of acceptance cultivation, individuals learn how to handle their internal states more

Table 2
Estimates for Linear Mixed Models in the acute stress sample for subjective stress, autonomous markers heart rate (HR) and high frequency heart rate variability (HF-HRV), and salivary cortisol. FFMQ: Five Facet Mindfulness Questionnaire (Baer et al., 2006), FMI: Freiburg Mindfulness Inventory (Buchheld et al., 2001; Walach et al., 2006).

Fixed Effects	Subjective Stress	HR	HF-HRV	Cortisol
Intercept	51.35***	4.57***	5.25***	2.21***
Time (rel. to stressor onset)	0.27***	0.01***	-0.02***	0.01***
FFMQ Describing	-1.47	0.02	0.23	-0.10*
FFMQ Observing	0.68	0.02	0.09	-0.03
FFMQ Non-judging	0.75	0.01	0.02	0.04
FFMQ Non-reacting	-0.05	-0.02	0.31	-0.05
FFMQ Acting with Awareness	-1.48	<0.01	-0.21	0.03
FMI Acceptance	-2.91**	<0.01	-0.28	0.04
FMI Presence	-0.61	-0.02	0.04	0.05
Time*FFMQ Describing	<-0.01	<0.01	<-0.01	<-0.01***
Time*FFMQ Observing	<0.01	<-0.01	0.01	<0.01
Time*FFMQ Non-judging	<0.01	<-0.01	<-0.01	<0.01
Time*FFMQ Non-reacting	0.01	<-0.01	0.01	<-0.01
Time*FFMQ Acting with Awareness	-0.01	<0.01	-0.01	<0.01*
Time*FMI Acceptance	-0.04*	<0.01	-0.01	<0.01
Time*FMI Presence	-0.02	<-0.01	<0.01	<0.01
Age	0.02	0.01	-0.45***	-0.10*
BMI		-0.01	-0.05	
Sex		0.01	0.04	
Time of Day				<-0.01***
Hormones				-0.12**
Random Effects	*SD*			
Subject (Intercept)	4.82	0.14	0.94	0.42
Residual	5.66	0.09	0.89	0.40

Note: <-0.01 indicates values between 0 and -0.01;
****p* ≤.001,
***p*≤.01,
**p*≤.05; for HR and HF-HRV after Bonferroni correction:
****p*≤.0005,
***p*≤.005,
**p*≤.025

Table 3
Estimates for Linear Models in the chronic stress sample for hair cortisol and hair cortisone. FFMQ: Five Facet Mindfulness Questionnaire (Baer et al., 2006), FMI: Freiburg Mindfulness Inventory (Buchheld et al., 2001; Walach et al., 2006).

	Hair cortisol	Hair cortisone
Intercept	1.73***	2.69***
FFMQ Describing	-0.13	-0.09
FFMQ Observing	0.08	0.14
FFMQ Non-judging	-0.08	-0.03
FFMQ Non-reacting	0.07	0.11
FFMQ Acting with Awareness	0.11	0.06
FMI Acceptance	0.05	-0.03
FMI Presence	<0.01	-0.08
Sex	-0.20	-0.31*
Age	0.12	0.08
R^2	0.06	0.09

Note:
****p*≤.0005
***p*≤.005
**p*≤.025 after Bonferroni correction

efficiently. Only then, stress reduction can take place. As we show here, higher trait levels of acceptance abilities seem to follow the same pattern of adaptivity.

Monitoring as understood in the MAT encompasses the mindfulness facets “Observing” (FFMQ) and “Presence” (FMI). “Non-reacting”, “Non-judging” (both FFMQ) and “Acceptance” (FMI) are subsumed under the construct of Acceptance (Lindsay and Creswell, 2017). FFMQ “Describing” and “Acting with Awareness” have not been conclusively classified by the MAT authors themselves. It should be noted in this context that there is an ongoing debate as to whether “Describing” (understood as the capacity to easily express ones feelings) is a facet of mindfulness in the first place (Grossman, 2008). Outside the MAT, “Acting with Awareness” has been suggested to be a facet of Monitoring (Di Francesco et al., 2017). Due to the fact that the FFMQ “Acting with Awareness” facet incorporates primarily the items of the Mindful Attention Awareness Scale (MAAS; Brown and Ryan, 2003), which was used in the study by Manigault et al. (2018), there is an expectedly high correlation between these two scales (Baer et al., 2006). Thus, although our results are not completely in line with prior studies, they very well mirror the assumptions of the MAT. And while evidence for the MAT has come from studies dismantling monitoring-only from acceptance-fostering meditation components (e.g. Creswell et al., 2014; Engert et al., 2017), the current data supports the accuracy of the theory also for pre-meditation traits.

There are several limitations to our study. First, it is based on a secondary, explorative data analysis that was not conceived in the conceptualization phase of the *ReSource* project, and not preregistered. Second, due to the design of the *ReSource* training study, we do not have the same number of participants for acute stress and hair cortisol data. Also, within the hair cortisol sample, we had a substantial sex imbalance. Third, although we directly address the study by Manigault et al. (2018), we did not use the same questionnaire to assess mindfulness, making a direct comparison of questionnaire scales impossible. Fourth, the FMI is partially embedded in the FFMQ questionnaire. It may therefore be considered redundant in the current analysis. Importantly, scales of both questionnaires showed no multicollinearity in our analyses. Further, the internal consistency of the FMI was found to be low for the “Presence” facet, particularly among non-meditators (Kohls et al., 2009), as tested here. We nevertheless included the FMI to be consistent with other publications of the *ReSource Project* (see Supplementary Material).

In conclusion, we here examined the association between different facets of trait mindfulness, as assessed with two questionnaires, the Five Facet Mindfulness Questionnaire (Baer et al., 2006) and the Freiburg Mindfulness Inventory (Buchheld et al., 2001; Walach et al., 2006), and two stress-related outcomes, psychosocial acute reactivity and chronic stress load. Our results allow us to tentatively address three important theoretical questions relevant for the construction of meditation-based mental training interventions aiming for stress reduction. First, we found that mixed previous findings on the relationship between trait mindfulness and stress reactivity can be explained by a more granular investigation into the mindfulness construct. Mindfulness is not one entity, but rather a complex construct, subsuming distinct qualities. Specifically, mindfulness facets of monitoring (FFMQ “Observing”, “Acting with Awareness”) were associated with higher stress load, both acute and (albeit only marginally) chronic, while acceptance-related facets (FMI “Acceptance”) and the ability to put one’s experience into words (FFMQ “Describing”) were associated with lower acute stress load. Second, we found that different stress markers (i.e., subjective, sympathetic, parasympathetic, and cortisol activity) differed in their individual associations with trait mindfulness. Third, we found tentative evidence that increased rather than decreased acute psychosocial stress reactivity can be interpreted as an indicator of a maladaptive stress response. Overall, our results indicate that not every facet of mindfulness is equally helpful for stress reduction. Indeed, in line with the assumptions of the MAT (Lindsay and Creswell, 2017, 2019), “monitoring”-related facets are actually associated with maladaptive patterns of stress responding. Although the MAT is conceptualized in the context of mindfulness training, we show a similar pattern of (mal-)adaptivity for mindfulness as a personality trait. The current results can serve as a valuable guide in the future conceptualization of mindfulness-based training programs towards successful stress reduction, as well as in the selection of appropriate markers and measures to evaluate training success.

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CRediT authorship contribution statement

Tania Singer: Writing – review & editing, Supervision, Methodology, Funding acquisition, Conceptualization, Project Administration. **Lara Puhlmann:** Writing – review & editing, Conceptualization. **Roman Linz:** Writing – review & editing, Conceptualization. **Mathilde Gallistl:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Veronika Engert:** Writing – review & editing, Supervision, Project administration, Methodology, Formal analysis, Conceptualization.

Declaration of Competing Interest

none.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.psyneuen.2024.107051.

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