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RESEARCH ARTICLE

Testing the monitor and acceptance theory: the role of training-induced changes in monitoring- and acceptance-related capacities after attention-based, socio-emotional, or socio-cognitive mental training in reducing cortisol stress reactivity

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ABSTRACT

Mindfulness-based interventions have become a popular means to reduce stress. However, the specific mechanisms driving observed stress reduction remain understudied. The Monitor and Acceptance Theory suggests that the cultivation of monitoring *and* acceptance skills are necessary moderators of practice-induced stress reduction. In the context of the *ReSource Project*, a large healthy adult sample underwent three 3-month mental training modules targeting either attentional (Presence module), socio-affective (Affect module) or socio-cognitive skills (Perspective module). In the current study, the development of a range of inter-individual differences in mindfulness-, interoception- and compassion-related traits - which mapped to either monitoring or acceptance categories - was tracked. The relationship of these training-induced changes with cortisol stress reactivity after the three distinct 3-month training modules was explored. We found that stress sensitivity was particularly modulated by a differential adaptivity of one cultivated attentional capacity - Attention regulation - which predicted higher cortisol reactivity after mere attention training (Presence) but was associated with lower stress-induced cortisol release after additional socio-affective and socio-cognitive practice (Affect and Perspective). However, this effect did not survive multiple comparisons correction, and analyses were limited by the sample size available. We conclude that our study provides preliminary support of the *Monitor and Acceptance Theory*, lending weight to the advantage of primary attentional increases in order to fully harness the beneficial effects of socio-affective training, ultimately leading to stress reduction. Although training-induced increases in acceptance were not directly shown to contribute to lowering cortisol stress reactivity, the data suggest an additional benefit of socio-affective and socio-cognitive training that is not directly captured within the current analyses. Our study corroborates the importance of going beyond the training of attention monitoring to foster stress resilience, and highlights that mental training relies on the co-development of several interacting processes to successfully attenuate stress. Further exploring the overarching concept of acceptance in future research may prove beneficial to the theoretical framework of MAT, and in understanding the processes by which stress reduction occurs.

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Cortisol; mindfulness; monitor and acceptance theory; stress reactivity

Introduction

Mindfulness-based mental training interventions have been studied extensively in recent decades to understand their efficacy in reducing stress and its related disorders (Baminiwatta & Solangaarachchi, 2021). While evidence for general salutogenic and stress-reducing effects are increasing (Engert et al., 2017; Khoury et al., 2015; Pascoe et al., 2017), identifying the active mechanisms underpinning such effects remains a prominent challenge in contemplative science (Creswell, 2017). In the current paper, we explore this question in the context of the ReSource Project (Singer et al., 2016), a 9-month longitudinal mental training study.

Among the most frequently reported effects of all meditation-based interventions are lowered subjective stress levels (Chiesa & Serretti, 2009; Khoury et al., 2015). Findings on physiological stress levels are less clear (Morton et al., 2020; Pascoe et al., 2017). Different intervention types and

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durations have shown an inconsistent pattern of effects on acute cortisol stress reactivity (for a review see (Morton et al., 2020).

The *Monitor and Acceptance Theory (*MAT; Lindsay & Creswell, 2017) suggests that stress reduction via mindfulness training occurs through first learning attentional and interoceptive capacities (monitoring), followed by the development of acceptance related capacities to manage the increased receptivity to internal signals (acceptance; Lindsay & Creswell, 2017). It posits that initial emotion agitation and symptom exacerbation are likely to happen as monitoring is learned (Creswell et al., 2014), as awareness to one's physiological state is increased, and attentional salience to both positive *and* negative emotional cues is enhanced. However, through cultivation of acceptance, individuals are suggested to deal with these emotional states more effectively, and thus stress reduction should occur.

The MAT notion of acceptance is broad ranging, encompassing a variety of sub-constructs such as non-reactivity, non-judgment, and openness (Lindsay & Creswell, 2017). Evidence for this theory comes from studies which dismantled acceptance-fostering components from classical MBSR training, thereby deconstructing mindfulness training into either monitoring-only, or monitoring and acceptance interventions. Compared to monitoring-only or no training, classical MBSR training (teaching both monitoring and acceptance skills) was found to lead to more positive daily-life affect (Lindsay et al., 2018), lower daily-life subjective stress (Chin et al., 2019), and lower stress-reactive cortisol levels (Lindsay et al., 2018). Together, studies deconstructing mindfulness practice have highlighted acceptance as a proposed key ingredient in the stress-reducing properties of mindfulness-based interventions (Lindsay & Creswell, 2019).

In the *ReSource Project,* (Singer et al., 2016), three distinct training modules were specifically developed to cultivate either attention and interoceptive awareness (Presence module), socio-affective (Affect module) or socio-cognitive abilities (Perspective module) in training-naïve participants (for full descriptions and theoretical background please refer to our methods section). Engert et al (2017) compared the stress-reducing effects of these distinct training modules. In line with previous research, all training modules led to reduced subjective stress following an acute socio-evaluative laboratory stressor, the Trier Social Stress Test (TSST; (Kirschbaum et al., 1993). Cortisol release, however, was markedly attenuated only after socio-affective and socio-cognitive training, but not after present-moment, attention-based practice (Engert et al., 2017). Nestled within the MAT framework, this pattern of results suggests that merely cultivating attentional and interoceptive skills may not suffice to buffer physiological stress reactivity. Despite reduced subjective stress levels (rather than emotional agitation, as suggested by the MAT), improved perception of bodily stress signals through improved monitoring ability may perpetuate rather than reduce physiological activation. Socio-affective and socio-cognitive capacities, such as acceptance and perspective taking, may be required in addition to attentional skills in order to effectively reduce the physiological stress load (Engert et al., 2017).

To date no study has explored how individual differences in explicitly measured attentional and acceptance-related skills, observed after different types of mental training, predict differences in stress reactivity. The participant sample of the *ReSource Project* was thus investigated on a more granular level, by relating self-reported mental training-induced changes in monitoring- and acceptance-based capacities with stress-reactive cortisol levels to the TSST. This was tested after training of one respective of the *ReSource* modules or module combinations (Presence, Affect, Perspective, or a combination of either Affect or Perspective after Presence). We hypothesized that the cultivation of monitoring skills as targeted in the attention-based Presence training would not be beneficial in lowering cortisol stress reactivity after Presence training only. However, the cultivation of acceptance-related skills after combined practice in the socio-affective and socio-cognitive modules (Affect and Perspective), was expected to be associated with lower cortisol stress reactivity.

Methods and materials

Participants

The study was conducted at the department of Social Neuroscience at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig and a satellite laboratory in Berlin. Data was collected between 2013 and 2016. Participant eligibility was determined through a multi-stage procedure that involved several screening and mental health questionnaires (for details see chapter 7 in Singer et al., (2016)). In short, to determine applicability for the *ReSource Project*, volunteers were examined via two face-to-face mental health diagnostic interviews led by a clinical psychologist, the Clinical interview for DSM-IV Axis-1 disorders (SCID-I DIA-X; (Wittchen & Pfister, 1997), and the SKID-II for Axis-II disorders (Maffei et al., 1997; Wittchen et al., 1999). 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, or any Axis-II within their lifetime. Exclusion also pertained if participants took any medication that influenced HPA axis activity. For the current study, all included participants had undergone at least three months of mental training and provided a measure of cortisol stress reactivity in the context of the TSST. Participants attending the TSST at the baseline measurement time-point (T0) or who were part of the training-free retest control cohort were consequently excluded (see Figure 1(B)). This resulted in a final sample of N = 183 (111 cisgender females, cisgender 72 males, mean age = 41.02) (see Engert et al., 2017 for details on study dropout and exclusion). Females were assessed on hormonal status via self-report on the day of stress testing, resulting in 65 females with a natural menstrual cycle, 28 females who did not menstruate due to menopause or polycystic ovary syndrome, and 18 females using hormonal contraceptives.

The *ReSource Project* was registered under the title 'Plasticity of the Compassionate Brain' with the Protocol Registration system (www.ClinicalTrials.gov) (identifier NCT01833104). The project was approved by the ethic boards of Leipzig University (ethic number: 376/12-ff) and Humboldt University Berlin

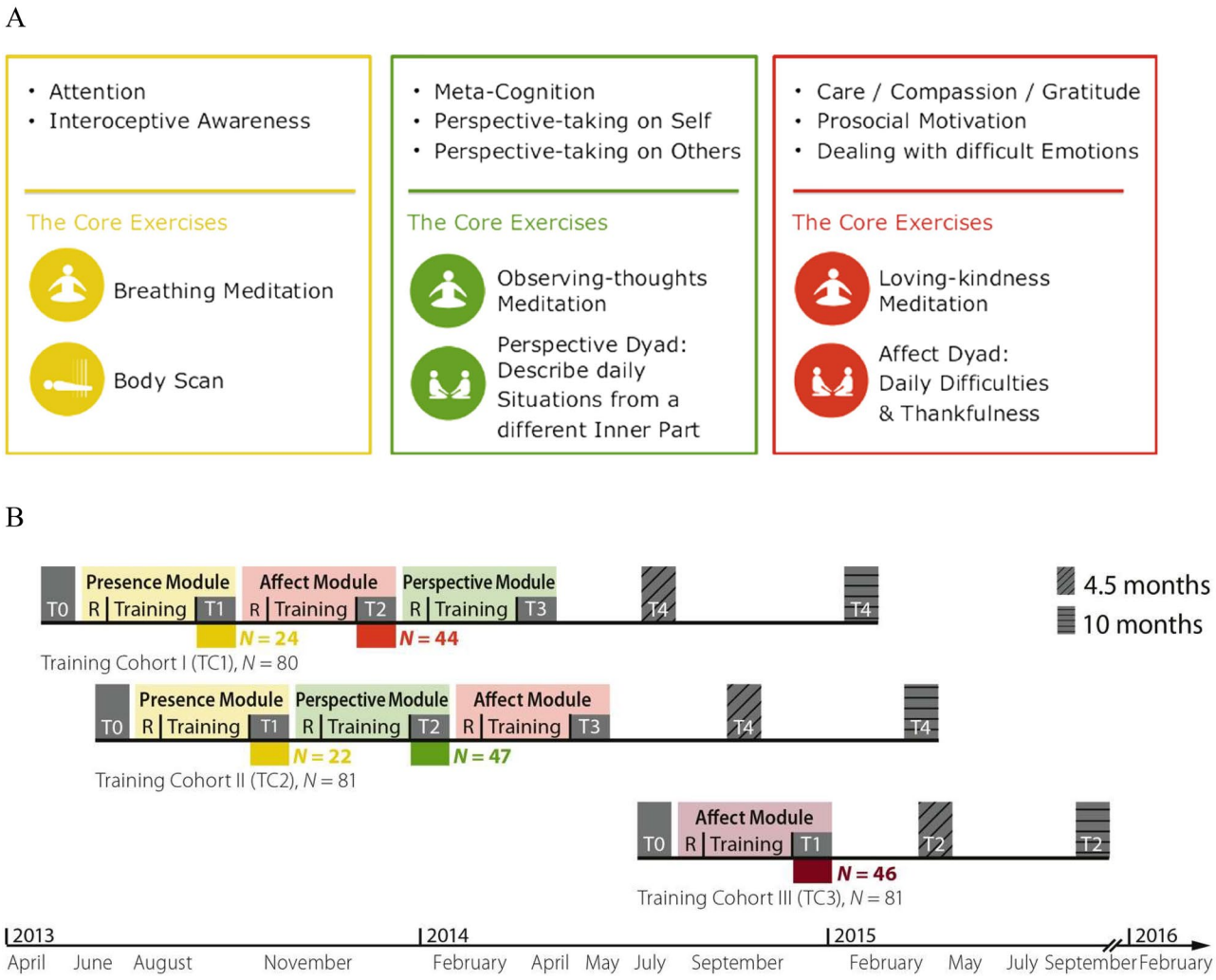

Figure 1. Study protocol and design. (A) Training modules and core exercises of the *ReSource Project*. In the Presence Module, attention and interoceptive body awareness are trained through the core practices Breathing Meditation and Body Scan. In the Affect Module, social emotions such as compassion, loving kindness, and gratitude are trained through the core practices Loving-kindness Meditation and Affect Dyad. The Perspective Module targets metacognition and perspective-taking on self and others. Core practices are Observing-thoughts Meditation and Perspective Dyad. The two contemplative dyads are partner exercises that were developed for the *ReSource* training. They address different skills (e.g gratitude, acceptance of difficult emotions and empathic listening in the Affect Dyad; perspective taking on self and others in the Perspective Dyad), but are similar in structure. In each 10-min dyadic practice, two randomly paired participants share their experiences with alternating roles of speaker and listener. For in depth description of the dyadic meditation type please refer to Singer et al (2016). (B) Design and timeline of the *ReSource Project*. Two training cohorts, TC1 (N = 80) and TC2 (N = 81), started their training with the mindful attention-based Presence Module. They then underwent the social Affect and Perspective Modules in different orders. The total training time for TC1 and TC2 was 39 weeks (13 weeks per module). TC3 (N = 81) only trained the Affect Module for 13 weeks. Time-points of cross-sectional stress testing in the Trier Social Stress Test (TSST) within the greater context of the *ReSource* training timeline and cohort membership of each participant are indicated. In detail, 44 participants attended the TSST at T1 following Presence (N = 23 from TC1, N = 21 from TC2), 45 at T1 following Affect, 44 at T2 following Presence and Affect (all from TC1), and 44 at T2 following Presence and Perspective (all from TC2) training. The remaining participants of the training cohorts were scheduled to do the TSST at T0. This allowed to show that the pre-training stress reactivity in the training cohorts did not differ from that of the retest control cohort. Both, training cohort participants tested at T0 and participants of the retest control cohort are not included in the current study, and therefore not depicted. No stress testing was executed at T3 or the follow-up measuring time-point T4 (T2 in TC3), which took place at either 4.5 or 10 months. Aff: Affect; Prs: Presence; Prs/Aff: Presence/Affect; Prs/Per: Presence/Perspective; TC: training cohort.

(ethic numbers: 2013-20, 2013-29, and 2014-10). Participants could withdraw from the study at any point and agreed to taking part via written informed consent. They were financially compensated for their time.

Although some of the data reported here have previously been published in the context of other research questions, either at the *ReSource* baseline testing time-point (e.g. Blasberg et al., 2022; Engert et al., 2016) or after training (Engert et al., 2017; Hildebrandt et al., 2017; Hoehne et al., 2022), none of these previous studies examined associations of training-induced changes in facets of self-report measures of mindfulness and acceptance with cortisol stress reactivity. In other words, the current manuscript brings data together in a completely new way and focuses on a new research question. The current study is an a-posteriori study not originally planned during the designing of the *ReSource Project*.

ReSource training program

All modules began the training with a 3-day intensive retreat. Following this, participants came into the institute for weekly (13 in total) teacher-guided group sessions and additionally carried out daily practice at home. Internet platforms and smartphone applications were specifically developed to provide audio streams for guided meditations.

As illustrated in Figure 1(A), the core psychological processes targeted in the Presence module are attention and interoceptive body awareness, which are trained through the two meditation-based core exercises Breathing Meditation and Body Scan. The Affect module targets the cultivation of social emotions such as compassion, loving kindness, and gratitude. It also aims to enhance prosocial motivation and dealing with difficult emotions. The two core exercises of the Affect module are Loving-kindness Meditation and Affect Dyad. In the Perspective module participants train meta-cognition and perspective-taking on the self and others through the two core exercises Observing-thoughts Meditation and Perspective Dyad. The modules were developed primarily to reflect different core principles and classifications of traditional Buddhist practices (Gethin, 1998; Lutz et al., 2007). Moreover, there is neuroscientific research which highlights differential brain networks that underlie the three mindfulness training types, that is, a) attentional processes (Petersen & Posner, 2012) 2012), (b) socio-affective processes, including emotions such as empathy and compassion, and (c) socio-cognitive processes, including the capacity to mentalize and take perspective on self and others (for details on the scientific backbone of this division see (de Vignemont & Singer, 2006; Singer & Lamm, 2009)).

The two contemplative dyads are partner exercises that were developed for the *ReSource* training (Kok & Singer, 2017). They address different skills such as gratitude, acceptance of difficult emotions and empathic listening (Affect Dyad) or perspective taking on self and others (Perspective Dyad), but are similar in structure (for details see Singer et al., 2016). In each 10-min dyadic practice, two randomly paired participants share their experiences with alternating roles of speaker and listener. The dyadic format is designed to foster interconnectedness by providing opportunities for self-disclosure and non-judgmental listening. For in depth description of the dyadic meditation type please refer to Singer et al (2016).

Our recommendation was to train for a minimum of 30 minutes on five days per week (e.g. the contemplative dyads were standardized to take exactly 10 minutes and were realized using the developed smartphone app; the classic meditations could be chosen from a range of 10-, 20-, 30- or 60-minute audio guides). The two types of mental exercises did not need to be carried out in immediate succession. However, as the dyadic practices had to be precedently organized with a respective dyadic partner, it required a higher level of interpersonal accountability and less flexibility as the classic meditation practice.

ReSource training design

Participants were divided in two 9-month training cohorts experiencing the modules in different orders, one 3-month Affect training cohort and one retest control cohort (RCC). Importantly, because we focus on the factors underlying training-induced changes in stress reactivity, data from the retest control cohort are not used in the present study. In detail, two training cohorts (TC1, TC2) started their training with the mindfulness-based Presence module. They then underwent Affect and Perspective modules in different orders thereby acting as mutual active control groups. To isolate the specific effects of the Presence module, a third training cohort (TC3) underwent the 3-month Affect module only (Figure 1(B)).

Most variables assessed in the *ReSource Project* (including the mindfulness-based and compassion-based questionnaires used in the current study) were tested longitudinally after each module. To that effect, participants provided self-reports on a wide range of questionnaires (see Singer et al., 2016 for a complete list), once prior to any intervention (T0) and subsequently after at least 12 weeks into practice of each module (T1-T3).

Because the TSST is not well suited for repeated assessments due to habituation processes, stress testing was carried out in a between-subjects design. Thus, each participant attended the TSST once and, as part of different participants groups, at different stages throughout the training ($n = 46$ at T1 following Presence, $n = 46$ at T1 following Affect, $n = 44$ at T2 following Presence and Affect, and $n = 47$ at T2 following Presence and Perspective training). For this cross-sectional stress testing design, groups were matched on a subset of variables with potential influence on stress reactivity: sex, hormonal status in women, city of residence (Berlin/Leipzig), number of smokers, age, depressed mood, trait anxiety, and chronic stress (for the concrete instruments and statistical tests used in the matching procedure see (Engert et al., 2017). Altogether $n = 130$ participants were excluded from the current work because they either attended the TSST either at the training baseline (T0; $n = 46$) or were part of the training-free retest control cohort (RCC; $n = 84$) (Figure 1(B).

Stress induction

To induce stress, a widely known standardized laboratory stress paradigm, the Trier Social Stress Test (TSST; Kirschbaum et al., 1993) was used. In this socio-evaluative stressor, participants perform a mock interview talk and carry out mental arithmetic in front of two alleged behavioral analysists, who provide no positive feedback and verbally probe the participant. The TSST reliably increases subjective psychological and physiological levels of stress through elements such as social-evaluative threat, unpredictability, and uncontrollability (Dickerson & Kemeny, 2004).

In our study, stress testing took place between noon and 6 pm to control for diurnal variation in cortisol release (Dallman et al., 2007). Upon arrival, participants had a standardized snack to equalize blood sugar levels. After resting for 15 minutes they took a saliva sample to measure baseline cortisol levels (at −55 minutes in relation to stress induction at 0 minutes), followed by a 30-minute resting phase. Participants were then provided with test instructions and given time to prepare for the test (10-minute anticipatory phase). After stress induction (between 0 and 10 minutes), saliva samples were taken at 20, 30, 40 and 55 minutes to assess peak cortisol stress levels and stress recovery. Throughout the testing procedure, participants refrained from eating and drinking anything apart from water.

Several other stress or stress-related markers (subjective-psychological stress, alpha-amylase release, heart rate and high frequency heart rate variability, as well as oxytocin, brain-derived neurotrophic factor, interleukin-6 and C-reactive protein release) were also assessed. These data were not differentially influenced by mental training and are therefore not subject to the current study.

Measures

Salivary cortisol

Cortisol was measured via saliva samples using Salivette collection devices (Sarstedt, Nuembrecht, Germany). Participants held the saliva collection swabs inside the mouth for two minutes without chewing. Subsequently, collection swabs were placed in a plastic container and stored at a temperature of −30 °C until assay. Cortisol levels (expressed in nmol/l) were determined in duplicate using a time-resolved fluorescence immunoassay (Dressendörfer et al., 1992; Lorentz et al., 1999), with intra- and interassay variabilities of less than 10 and 12%, respectively. Samples were collected at −55, 20, 30, 40 and 55 minutes relative to stressor onset (at 0 min).

Self-report questionnaires

Changes in mindfulness- and acceptance-based facets were measured via questionnaires to pinpoint which specific capacities learned were modulating training-induced changes in cortisol stress reactivity. Questionnaires were chosen from the bulk of questionnaires administered in the *ReSource Project,* based on their capacity to measure either attention/monitoring- or acceptance-related capacities. Previous *ReSource* findings from the same participants have already indicated that increases in attention and acceptance related capacities occurred after specific training: The Presence module increased self-reports of mindfulness facets such as observing, non-reacting and presence. The compassion-based and socio-cognitive modules improved a broader range of facets including acceptance and non-judgment, compassion and self-compassion, emotion regulation and coping strategies (Hildebrandt et al., 2017, 2019). Building on these findings, we investigated all questionnaires as listed below. Specific subscales were chosen based on their capability to assess monitoring or acceptance. For example, although the Five Factor Mindfulness Questionnaire broadly assesses 'mindfulness', the describing subscale, which assess how accurately participants can label their experiences, is not per se a direct trait of monitoring, and was therefore excluded. Aiming to substantiate the questionnaires' associational pattern into attention/monitoring and acceptance capacities, we conducted an exploratory network analysis (Figure 2) including questionnaire data from the baseline measurement time-point for all n = 332 participants of the ReSource study.

Freiburg mindfulness inventory. The Freiburg Mindfulness Inventory (FMI; Walach et al., 2006), was developed through interviews of experienced meditators and subsequently tested in non-meditators in order to form a shorter version. It has 14 items, which represent the two dimensions Presence (awareness of experience) and Acceptance (non-judgmental acceptance of experience) (Kohls et al., 2009). Both subscales were included in the current analysis; the Presence subscale to capture monitoring, and the Acceptance subscale to capture acceptance capacities.

Five facet mindfulness questionnaire. The Five Facet Mindfulness Questionnaire (FFMQ; Baer et al., 2006), has 39 items and was developed through factor analysis, extracting five sub-factors of mindfulness: Non-reacting to inner experiences, Observing inner experiences, Acting with awareness, Describing and Nonjudging of experience. It was designed to address the lack of operationalization of mindfulness. Four of these subscales were included in our analysis; Observing and Acting with awareness to capture monitoring capacity, and Non-reacting and Non-judging to capture acceptance capacity.

Self-compassion scale. The Self-Compassion Scale (SCS; Neff, 1995) is a 26-item questionnaire which consists of six subscales: Self-kindness, Self-judgment, Common humanity, Isolation, Mindfulness, and Overidentification. These subscales are opposing spectral ends, with overidentification measuring the opposite of mindfulness, self-judgment opposing self-kindness, and isolation opposing common humanity. Two subscales were included in this analysis; Mindfulness and Self-judgement both under the acceptance capacity.

Compassion for others scale. The Compassion for Others Scale (CS; Pommier et al., 2020), has similar subscales as the SCS, but is directed at how respondents relate to others' suffering. It has 16 items and consists of six subscales: Kindness, Indifference, Common humanity, Separation, Mindfulness, and Disengagement. Similar to the SCS, these subscales represent pairs of opposing constructs. One subscale – Mindfulness – was chosen and included in this analysis under the capacity of monitoring.

Multidimensional assessment of interoceptive awareness. The Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012), is a 32-item state-trait questionnaire, designed to measure the multifaceted physiological and emotional components of interoceptive awareness. These are subdivided into five broad categories: Awareness of body sensations, Emotional reaction and attentional response to sensations, Capacity to regulate attention, Trusting body sensations and Mind-body integration. The categories are further divided into more specific dimensions, namely, Noticing, Not-distracting, Not-worrying, Attentional regulation, Emotional Awareness, Self-regulation, Body listening and Trusting. Five subscales were included in the current analysis, all of which under monitoring capacity – Attention regulation, Body listening, Emotional awareness, Noticing and Not-distracting.

Cognitive emotion regulation questionnaire. The Cognitive Emotion Regulation Questionnaire consists of 36 items which can be subdivided into 9 subscales (CERQ; Jermann et al.,

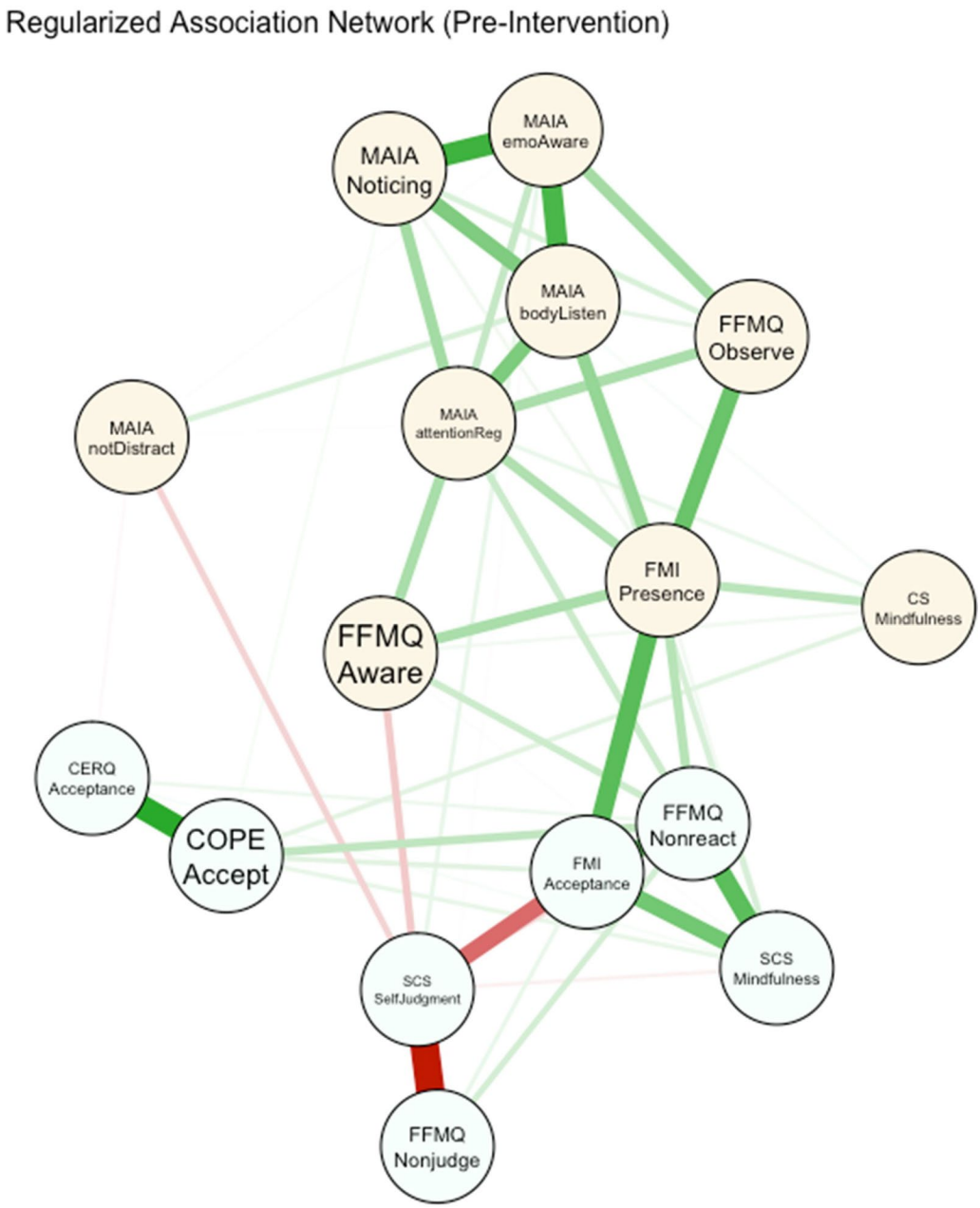

Figure 2. Regularized partial correlations network. This network depicts interrelations (network nodes) between self-reports of mindfulness components assessed at the *ReSource* baseline measurement time-point (T0). The structure of the network was consistent with the grouping of attention/monitoring and acceptance skills, as hypothesized by the Monitor and Acceptance Theory (MAT). Node colors represent the a-priori grouping of the respective subcomponents (beige = attention/monitoring; blue = acceptance). Closer proximity between nodes depicts higher correlations; green edges show positive and red edges negative associations between nodes.

2006), and assesses different cognitive emotion regulation strategies that individuals use following negatively affective circumstances and situations. The subscales are Self-blame, Blaming others, Acceptance, Refocusing on planning, Positive refocusing, Rumination, Positive reappraisal, Putting into perspective and Catastrophizing. The Acceptance subscale was included in our analysis under the capacity of acceptance.

Coping orientation to problems experiences. The German language version of the brief Coping Orientation to Problems Experiences (COPE; Carver et al., 1989) is a 14-subscale questionnaire designed to measure the ways in which individuals cope with a stressful life event. It includes positive and negative strategies, such as Activity, Use of informational support, Positive reframing, Planning, Emotional support, Venting, Humor, Acceptance, Religion, Self-blame, Self-distraction, Denial, Substance use, and Behavioral disengagement. The subscale of Acceptance was included in our analysis under the capacity of acceptance.

Statistical analysis

Data preparation

Analyses were carried out using R (Version 4.0.2; **R** Core Team, 2020). Statistical significance for hypothesis testing was set at $\alpha \leq 0.05$, and $\alpha \leq .1$ for statistical trend level. To interpret

effect size, the guidelines of Cohen (2013) were used, which specify partial eta squared value: 0.10 = small effect size; 0.59 = medium effect size; and .138 = large effect size.

Cortisol stress reactivity was calculated as a change score by subtracting participants' cortisol study baseline levels (-55 min before TSST onset) from cortisol peak levels (sample average at +20 min after stressor onset). These cortisol change scores were baseline-residualized to adjust for potential effects of baseline values on stress-induced cortisol release (Tu & Gilthorpe, 2007), and subsequently served as proxy for cortisol reactivity in all main analyses. Second, training-induced change in all selected questionnaires was calculated by subtracting the pre-intervention baseline (T0) scores from the scores corresponding to the respective time-point at which participants underwent stress testing.

Exploratory network analysis

In an initial exploratory network analysis, a correlation network was constructed to visualize the interrelations between all the selected questionnaire subscales and verify whether they fell into the broad categories of monitoring and acceptance, as would be suggested by the MAT. Such concentration networks reveal the relational pattern of all network nodes (questionnaire subscales) resulting from multivariate partial correlations. The network was calculated using the r package *qgraph* (Epskamp & Fried, 2018). Based on a partial correlation matrix, the network was regularized using a graphical least absolute shrinkage and selection operator approach (GLASSO; Friedman et al., 2008) with extended Bayesian information criteria (EBIC; Chen & Chen, 2008). In brief, this regularization determines more sparse networks by limiting spurious associations between variables, and thus facilitates interpretability and reproducibility of the obtained networks (Epskamp & Fried, 2018). The network was fit on all available N = 332 participants' pre-intervention questionnaire scores (measured at T0).

Main analysis

The r packages *lme4* and *car* were used for our main analyses. In detail, a linear regression model was chosen to statistically test the hypothesized effects laid out in the MAT framework. Changes in attention and acceptance scores were added as predictors, resulting in a model including all available self-report changes. These predictors were modeled in relation to cortisol stress reactivity (change scores) as dependent variable. Differences between modules (or module combinations) in a respective predictor were modeled using an interaction term module*predictor. When omnibus tests revealed a significant module*predictor interaction, simple effects were analyzed to specifically compare the Presence module to all other modules and module combinations. Due to known influences on cortisol reactivity, the model included the covariates hormonal status (Kajantie & Phillips, 2006) and time of day when conducting the TSST (Kirschbaum & Hellhammer, 1989). Due to the appreciable age range of participants (20 to 55 years), and to provide consistency across *ReSource* publications, age was also added as a covariate. Potential cases of variance inflation were investigated (VIF function of the r package *car*), revealing no indication of heightened variance inflation of regressors (all $GVIF^{1/(2.DF)} < 1.29$) (Fox & Monette, 1992).

Results

Exploratory network analysis

A correlation matrix showing associations between all self-reported change in questionnaire data is shown in Figure S1 (Supplementary Materials). An exploratory network analysis was conducted to visualize the interrelations between the utilized questionnaire scales assessed at the pre-intervention measurement time-point (T0) in N = 332 participants, and thus served to substantiate the questionnaires' associational pattern into attention/monitoring and acceptance capacities (Figure 2). The network's structure was largely consistent with the MAT-based grouping into attention/monitoring and acceptance skills. Questionnaire subscales relating to interoceptive qualities (MAIA) showed strong positive connections (green network edges) among each other, but were also positively connected to FFMQ and FMI subscales describing the mindfulness facets of awareness, observing and presence. A second pole of the network originated from negative connections (red edges) of SCS self-judgement to the theoretically opposed facets of non-judging (FFMQ) and acceptance (FMI). The latter also positively connected to FFMQ non-reacting, and to a sub-cluster comprising acceptance-based coping and emotion regulation facets (CERQ and COPE). Overall, not only subscales of the same questionnaires were closely connected (method clustering), but close connections between conceptually similar nodes were found, which broadly conforms to the investigated categories monitoring and acceptance.

Main analysis

A linear regression model investigated whether practice-induced changes in monitoring- and/or acceptance-related self-reports interacted with a respective training module in predicting cortisol reactivity. To this aim, change scores of all investigated self-reports served as predictors, targeting simultaneously the hypotheses that monitoring skills would not be beneficial in lowering cortisol reactivity after Presence training only, but that cultivation of acceptance-related skills after combined practice of socio-affective or socio-cognitive (Affect and Perspective) with attentional training (Presence) would be associated with lower cortisol stress reactivity.

The regression showed a significant interaction term of MAIA Attention regulation*module of medium effect size ($F = 2.79$, $p = 0.043$, partial eta-squared $\eta_p^2 = 0.070$) and a marginally significant interaction term of FMI Presence*module of medium effect size ($F = 2.19$, $p = 0.092$, partial eta-squared $\eta_p^2 = 0.060$). In detail, while after only Presence training increases in Attention regulation were associated with higher cortisol reactivity, the inverse pattern was found after both Affect and

Perspective after Presence training and for Affect training alone. There were no significant effects of any acceptance scale in predicting cortisol reactivity. A Benjamini-Hochberg false discovery rate correction for multiple comparisons was conducted; following this adjustment the test no longer yielded statistically significant results.

Further exploratory analyses were conducted to allow for a more comprehensive interpretation of the data. We explored all predictors' simple slopes by module to contrast Presence to the other modules/module combinations Table 1 (see Supplementary Materials and Table S1 for details). Consistent with the above reported pattern of results, practice-induced changes in Body Listening (MAIA) and Awareness (FFMQ) were found to predominantly differentiate Presence from the other modules regarding their prediction of cortisol reactivity (see Figure S2). Moreover, the FFMQ scales Nonjudging and Awareness specifically showed a difference of Presence and Affect after Presence.

Discussion

Understanding the specific processes driving stress-reduction after mindfulness-and compassion-based mental training has been a central aim in contemplative science (Creswell & Lindsay, 2015; Fan et al., 2014). As is claimed in the *Monitor and Acceptance Theory (*MAT; Lindsay & Creswell, 2017), fostering mental resources beyond purely attentional/monitoring skills may be necessary to reduce individuals' physiological stress load (Chin et al., 2019; Engert et al., 2017; Lindsay et al., 2018).

The current study linked participants' practice-induced changes in attention/monitoring and acceptance capacities to their stress reactive cortisol levels after different types of mental training. Stress reactivity was probed using a standardized psychosocial laboratory stressor, the Trier Social Stress Test (TSST; Kirschbaum et al., 1993). Monitoring- and acceptance-related skills were repeatedly assessed with the FMI (Kohls et al., 2009) FFMQ (Baer et al., 2006), MAIA (Mehling et al., 2012), SCS (Neff, 1995), CS (Pommier et al., 2020), CERQ (Jermann et al., 2006), and COPE (Carver et al., 1989) questionnaires. Participants completed distinct mental training modules cultivating either attentional and interoceptive (Presence), socio-emotional (Affect) or socio-cognitive capacities (Perspective).

An exploratory network analysis first revealed that the selected attention- and acceptance-based questionnaire scales largely reflected the two components of the MAT (monitoring and acceptance) (Lindsay & Creswell, 2017, 2019). In our main analysis, individual differences in cortisol reactivity after mindfulness-based training were most prominently associated with changes in attentional and interoceptive capacities, assessed as Attention regulation (MAIA; Mehling et al., 2012, see Figure 3). A trend level effect was also found for Presence (FMI; Walach et al., 2006, see Figure 4). Because these results do not survive multiple comparisons correction, they must be considered as preliminary until replicated in a different (and substantially larger) sample.

The adaptivity of changes in attention and interoception capacity was dependent on whether participants exclusively trained the Presence module, or a combination of the Presence module with one of the two social modules (Affect or Perspective). Thus, according with the MAT and our first hypothesis, while attention-focused mindfulness training alone boosted attention- and monitoring skills, this enhancement led to increases in cortisol stress reactivity following psychosocial challenge. Only after additionally training social skills, enhanced attention and interoception promoted a reduction in psychosocial stress reactivity.

MAIA attention regulation was highlighted as the component driving change in acute cortisol stress reactivity (Figure 3). It refers to the (interoceptive) ability to regulate one's attentional capacity back to the internal environment of the

Table 1. Omnibus tests of interaction terms (module*predictor).

Predictors	Df	Sum Sq	Mean Sq	F Value	*p*-value.	Partial eta^2	Adjusted p-value (FDR)	Model R^2	Adjusted R^2
								0.454	0.076
Age	1	0.616	0.616	0.922	0.339	0.009	0.616		
Hormones	3	6.843	2.281	3.412	0.020	0.090	0.333		
Start Time	1	0.184	0.184	0.275	0.601	0.003	0.751		
Module	3	5.394	1.798	2.689	0.050	0.070	0.333		
Module*									
FFMQ Observe	3	1.377	0.459	0.687	0.562	0.020	0.751		
FFMQ Aware	3	2.712	0.904	1.352	0.262	0.040	0.616		
MAIA Noticing	3	3.525	1.175	1.758	0.160	0.050	0.616		
MAIA Attention Regulation	3	5.608	1.869	2.796	0.044	0.070	0.333		
MAIA Emotional Awareness	3	2.063	0.688	1.029	0.383	0.030	0.638		
MAIA Body Listening	3	2.300	0.767	1.147	0.334	0.030	0.616		
MAIA Not distracting	3	1.778	0.593	0.887	0.451	0.020	0.694		
SCS Mindfulness	3	0.911	0.304	0.454	0.715	0.010	0.794		
CS Mindfulness	3	2.578	0.859	1.285	0.283	0.040	0.616		
FMI Presence	3	4.412	1.471	2.200	0.093	0..060	0.564		
FFMQ Non-Judge	3	2.577	0.859	1.285	0.284	0.040	0.616		
FFMQ Non-react	3	0.801	0.267	0.399	0.754	0.010	0.794		
SCS Self-Judgement	3	0.607	0.202	0.303	0.824	0.008	0.824		
FMI Acceptance	3	3.187	1.062	1.589	0.196	0.040	0.616		
CERQ Acceptance	3	1.118	0.373	0.557	0.644	0.020	0.758		
COPE Acceptance	3	1.264	0.421	0.630	0.597	0.020	0.751		

Notes: CERQ: Cognitive Emotion Regulation Questionnaire; COPE: Coping Orientation to Problems Experiences; FMI: Freiburg Mindfulness Inventory; FFMQ: Five Factor Mindfulness Questionnaire.

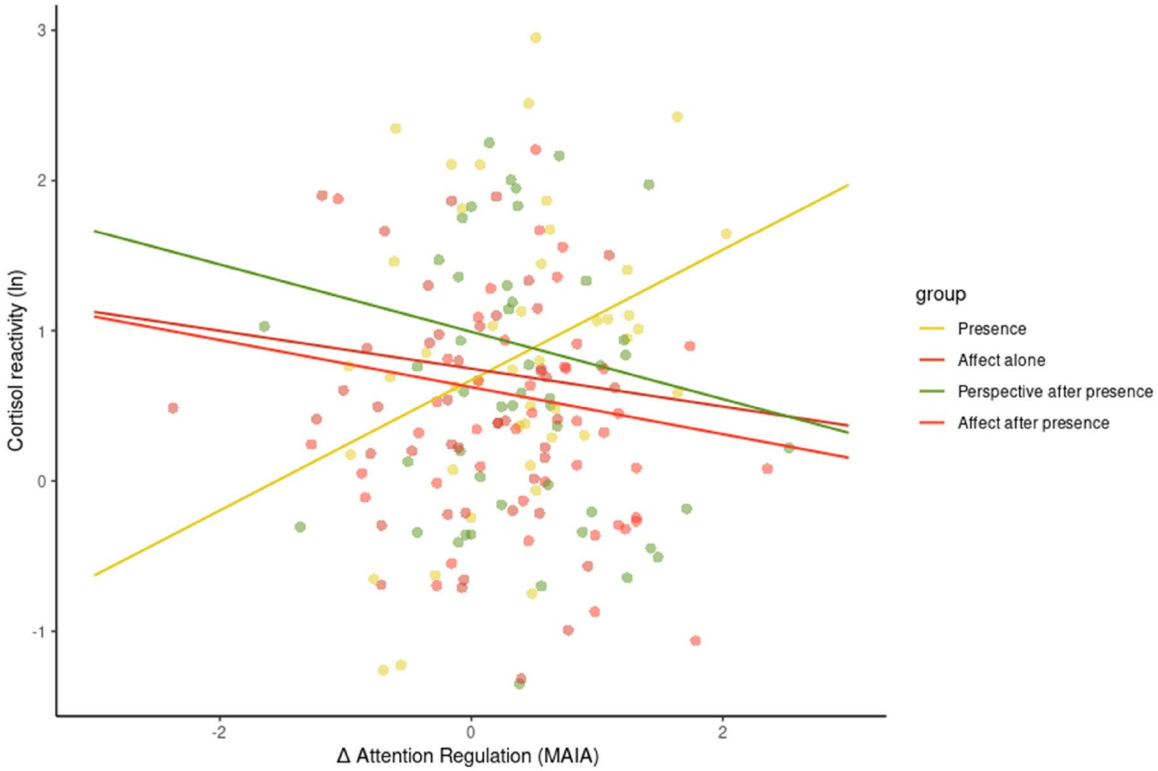

Figure 3. Association of cortisol stress reactivity and training-induced changes in MAIA Attention regulation. There was an interaction of Attention regulation, as measured with the Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012) with the factor module ($F = 2.796$, $p = 0.04$). In detail, the relationship of MAIA Attention regulation and cortisol reactivity was trend level different for Presence vs. Perspective after Presence ($t = -1.830$, $p = 0.070$), and also marginally different for Affect ($t = -1.709$, $p = 0.090$), but not Presence vs. both Affect after Presence ($t = -1.254$, $p = 0.213$). While after Presence training, increases in attention regulation were associated with higher cortisol reactivity, the inverse pattern was found after both Affect and Perspective training. Lines represent simple slopes per module; points represent predicted values. Significances regard differences in slopes comparing Presence to all other modules. $^{*}p < 0.05$; $^{\#}p < 0.1$.

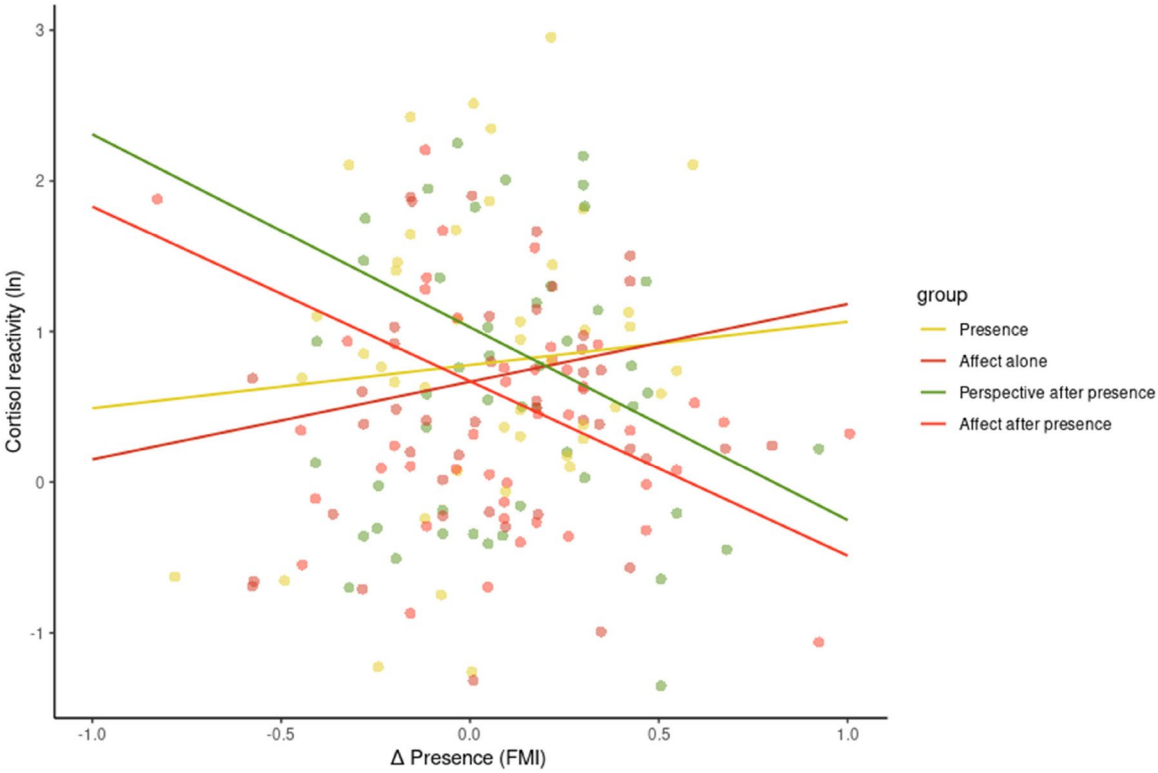

Figure 4. Association of cortisol stress reactivity and training-induced changes in FMI Presence. There was a trend-level interaction of Presence, as measured with the Freiburg Mindfulness Inventory (FMI; (Walach et al., 2006), with the factor module ($F = 2.200$, $p = 0.093$). In detail, FMI Presence and cortisol reactivity most strongly differed between Presence and Perspective after Presence training ($t = -1.610$, $p = 0.110$). The difference between Presence and Affect after Presence training was not significant but pointed toward the same direction numerically ($t = -0.062$, $p = 0.951$). Likewise, Presence and Affect training alone did not differ ($t = 1.082$, $p = 0.282$). While after additional Perspective training (and similarly, but to a lesser extent, after additional Affect training), increases in FMI Presence were associated with lower cortisol reactivity, the inverse pattern was found after Presence or Affect training alone. Lines represent simple slopes per module; points represent predicted values. Significances regard differences in slopes comparing Presence to all other modules. $^{*}p < 0.05$; $^{\#}p < 0.1$.

body. Clearly, a heightened focus on the body during acute stress may perpetuate stressful arousal, leading to overwhelming feelings of unease and tenseness in lack of the socio-emotional or -cognitive tools required for a more accepting or compassionate stance toward oneself, the scenario and one's present moment experience therein. A trend of FMI Presence in the same direction likely reflects similar internal processes (Figure 4). The FMI Presence subscale refers to mindfulness within a present-moment perspective. A heightened present-moment focus and increased reliance on the current state in guiding subjective experience may elicit stronger negative thoughts and feelings when confronted with the unpredictable TSST situation, which in its evaluative fashion may threaten an individual's ego. Conversely, after having developed additional mental capacities enabling a more accepting view on the self and situational state, responding with equanimity to the present experience may have beneficial effects on physiological stress levels.

Our findings partially conform to the notion of the MAT that the cultivation of attentional skills through mindfulness practice is an important step in ultimately reducing stress reactivity. When initially fostering interoceptive and attentional qualities, mindfulness practice may enhance stress sensitivity and increase stress-induced cortisol release. Lindsay & Creswell (2019) state that only once a stance of acceptance and equanimity accompanies the present moment focus, can mindfulness meditation exert its stress-reducing effects.

While specific acceptance effects modulating cortisol reactivity were not detected in the present analyses, our data do show that mental practices targeting resources beyond attention and interoception, such as care, accepting difficult emotions and (self-)compassion (Affect module) or perspective taking on self and others (Perspective module) show beneficial effects in the acute stress context. Previous investigations within the *ReSource Project* demonstrated that acceptance-related capacities are harnessed in both the Affect and Perspective modules, including changes in scales measuring non-judgement and self-compassion (Hildebrandt et al., 2017). Further, adaptive emotion regulation strategies were found to be fostered after Affect and Perspective, but not after pure Presence practice (Hildebrandt et al., 2019).

Additional evidence for the assumptions of the MAT (aside from our own work in the same participant sample as studied here; Engert et al., 2017) stems from studies showing that pure attention training was less efficient in lowering acute cortisol stress reactivity than combined attention/monitoring and acceptance practice (Chin et al., 2019; Lindsay et al., 2018). Moreover, a brief mindfulness training was shown to increase stress-induced cortisol release (Creswell et al., 2014). This could be due to the multifaceted nature of acceptance requiring longer training duration than attention-based skills. The current findings contribute to this literature, providing direct evidence of how inter-individual differences in the cultivated attention-based capacities promote stress reduction.

We suggest the dyadic exercises cultivated in the social modules may have been instrumental for the reduction in cortisol stress reactivity. This dyadic practice was shown to increase feelings of social connectedness and emotional disclosure (Kok & Singer, 2017), skills that are likely an impactful buffer against socio-evaluative stress. Regular self-disclosure of negative feelings and concomitant bodily states may have helped in stopping the vicious cycle where the realization of being stressed induces yet higher stress levels. Given the social nature of the TSST, training acceptance in a dyadic social context may also exert beneficial effects on reducing the threat of negative evaluation. Future research will have to further disentangle the differential effects of different types of socio-emotional and socio-cognitive practices in boosting acceptance as driving mechanism for mental health outcomes.

Although our results are principally in line with the MAT – that a combination of attention and acceptance training (Affect or Perspective *after* Presence) drives the reduction in stress reactivity, rather than attention (Presence) or acceptance (Affect) alone – the combination of training modules also reflected greater overall training time. This raises the question of whether the current results should be viewed as general effects of training duration rather than module-specific effects. Our findings rather suggest the prior, in showing biggest differences between the (3-month) Presence module and the 6-month module combinations (Affect and Perspective after Presence), and a relatively smaller difference between the two 3-month modules (Presence vs. Affect alone). Because in the current study the TSST was conducted only once per participant (due to habituation effects with repeated exposure), full statistical control of time and module effects was unfortunately not possible.

It should also be noted that we only tested for an influence of monitoring and acceptance change on cortisol stress reactivity for the specific reason that only cortisol stress reactivity was differentially affected by the Presence and Affect modules of the ReSource training. While subjective stress levels decreased overall, other markers (e.g. alpha-amylase, heart rate, brain derived neurotrophic factor) showed no change (Engert et al., 2017). Although cortisol has received most attention in comparative training studies testing the MAT assumptions (Lindsay et al., 2018) prior studies have found the MAT assumptions confirmed also regarding emotional and autonomic outcomes (Lindsday & Creswell., 2019). One study already investigated the MAT on further stress outcomes, finding that those who reported monitoring and acceptance skills had lower levels of IL-6 (Tomfohr et al., 2015). The MAT would continue to benefit from future research, investigating the mechanistic underpinnings of mindfulness of a range of wider biophysiological outcomes.

This study has several limitations. First and foremost, the tested sample was underpowered for the specific analysis conducted. In line with this, we did not find effects of the majority of the included questionnaire scales on acute cortisol stress reactivity. Of those that we did find, the effect sizes were relatively small and results did not survive correction for multiple comparisons. Apart from the small sample size, this lack of significant results compared to previous investigations (e.g. Creswell et al., 2014; Lindsay et al., 2018) may be due to the fact that we investigated training induced *change*, as opposed to overall levels of attentional and acceptance skills. Because changes in the measured abilities were only small,

detecting small effects may have been particularly difficult. Given the abundant evidence in support of the MAT, we believe that a more powerful dataset can substantiate the potential of training-induced changes in monitoring- and acceptance-related capacities as a mechanism of stress reduction. In this respect, we treat our results with the upmost caution, and refer to them as preliminary. We encourage future research to replicate and build on this specific aspect of the theory.

Second, the validity of measuring mindfulness via self-reports has been repeatedly questioned (Grossman, 2011, 2019). Demand characteristics may conflate individuals' dispositions with their desire to be mindful, interoceptive or compassionate, and lead to exaggerations in the aptitude of these qualities (Grossman, 2011). Third, several different self-report questionnaires measuring distinct mindfulness-based facets have been developed (for a recent review see (Baer, 2019)). While Creswell and colleagues (2019) specifically mention the FFMQ as a tool to test the MAT implications, in the current analyses, none of the FFMQ scales reached significance in predicting stress reactivity. Some scholars have suggested that the FFMQ may not yield the specificity to mindfulness that it claims, and instead merely reflects broader psychological changes (Goldberg et al., 2016; van Dam et al., 2012). Conversely, the version of the FMI used here is compartmentalized into only two simple subscales, Presence and Acceptance, which precisely parallels the constructs of the MAT. Future research should carefully consider how to use questionnaires or even behavioral tasks to measure attention and acceptance within this context. The present study focused on granularity in order to determine specific changes driving stress reactivity. Alternatively, it could be considered to build composite scores or focus solely on the FMI scale to distinctly divide mindfulness into the components as suggested by the MAT, and as traditionally taught in mindfulness practice.

Fourth, whilst quite a few scales exist measuring mindfulness and associated attentional and monitoring capacities, there is a lack of well-validated acceptance measures. Although related, non-judgement and self-compassion, as captured here, are not acceptance per se. It is difficult to measure a concept, which by its own definition is multifaceted and lacks specificity. A well-developed meaning of acceptance is critical for its functional testing in mindfulness research. Future research should develop better-suited questionnaires and computer-tasks to assess crucial aspects of acceptance.

Finally, our participants underwent a comprehensive health-screening, which limits generalization of the current findings to high-stress samples and clinical populations.

Conclusion

We examined how cultivating different aspects of attention- and acceptance-related skills reduces the cortisol response to psychosocial stress. Participants underwent a longitudinal mental training intervention with three distinct 3-month training modules focusing on training a) attention-based mindfulness, b) socio-emotional and c) socio-cognitive skills. Our findings suggest that attentional and interoceptive mechanisms may show differential adaptability in physiological stress reduction. Largely conforming to the MAT (Lindsay & Creswell, 2017), they may demonstrate that mere attention-based practices enhances stress sensitivity and thus increases the acute cortisol stress response. Only once socio-affective or cognitive skills were practiced, gains in attentional capacities were linked to lower cortisol stress levels. Reinforcing the view that practice effects in the realm of mental training rely on the co-development of several interacting processes, the current findings inform contemplative interventions aiming to alleviate individuals' stress load and more generally human suffering. Nonetheless, these results have a small effect size, and do not survive multiple comparisons correction. Rather than disregarding these findings completely, we suggest treating them cautiously, and invite higher powered follow up studies.

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Author contributions

R.L. and B.O.M. analyzed the data. R.L. and B.O. M drafted the manuscript. V.E. designed the study and supported data curation and the drafting of the manuscript. T.S. initiated and developed the *ReSource* Project, developed the intervention protocol and secured all funding. She also co-developed all stress-related measures and tasks as PI of the *ReSource* Project and was leader of all *ReSource* related meetings with her entire staff including meetings with the teachers, the researchers, the *ReSource* support and testing staff etc. All authors critically revised the manuscript.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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