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Investigating the impact of distinct contemplative mental trainings on daily life stress, thoughts and affect—Evidence from a nine-month longitudinal ecological momentary assessment study

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ABSTRACT

Mindfulness-based mental training interventions have become a popular means to alleviate stress and stress-associated health risks. Previous scientific investigations emphasize the importance of exploring the effects of such interventions in naturalistic settings to evaluate their implementation into daily life. Therefore, the current study examined the effects of three distinct mental training modules on a range of measures of daily life experience in the scope of the *ReSource Project*, a 9-month longitudinal mental training study comparing modules targeting attention and interoception (Presence), socio-affective (Affect) or socio-cognitive abilities (Perspective). We used ecological momentary assessment (EMA) to repeatedly probe levels of stress and stress-coping efficacy combined with stress-reactive cortisol levels, and further explored arousal, affective states, and thought patterns in the daily lives of 289 healthy adults (172 women; 20–55 years). We found increased presence-focused thought and heightened arousal after a training duration of 3–6 months, independent of the type of prior training. Increased coping efficacy emerged specifically after socio-cognitive Perspective training, following 6–9 months of training duration. No training effects were found for subjective stress, stress-reactive cortisol levels, or daily life affect. Our findings corroborate and add ecological validity to previous *ReSource* findings by showing that they replicate in participants' everyday environment. Regarding endocrine and subjective stress markers, our results suggest caution in generalizing acute laboratory findings to individuals' everyday routines. Overall, the current study provides substantiated insights into how cultivating one's mind through contemplative mental training translates to daily life experience, enhances stress-coping, and may ultimately aide in maintaining health.

1. Introduction

The continuously high prevalence of stress and increasing mental health challenges call for strategies to foster resilience and maintain health and well-being (Langgartner et al., 2019; Patel et al., 2018; Vigo et al., 2016). Mindfulness- and compassion-based mental training interventions have received substantial interest for their potential as prevention and treatment measures against excessive stress and its far-reaching health sequelae (Goyal et al., 2014; Hofmann et al., 2011; Wielgosz et al., 2019). In addition to describing salutogenic effects on mental- and somatic health outcomes, the growing scientific literature highlights the positive impact of a broad range of mental resources, cultivated through mental training, on practitioners' wellbeing (Goldberg et al., 2018; Khoury et al., 2015; Sedlmeier et al., 2012; Singer and Engert, 2019).

Stress reduction is an inherent claim of most secularized mental training programs. It is most explicitly targeted in the Mindfulness-based Stress Reduction program (MBSR; Kabat-Zinn, 1990), but also in compassion-based programs such as the Compassion Focused Therapy (Gilbert, 2009), which train socio-affective skills to foster mental health.

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Indeed, reductions in subjective stress levels are consistently reported across different types of programs (Chin et al., 2019; Creswell et al., 2019; Galante et al., 2014; Khoury et al., 2015). Regarding physiological stress levels – in particular levels of cortisol as a marker of hypothalamic-pituitary-adrenal (HPA) axis activation – findings are more dependent on the study context and -population (Koncz et al., 2021; O'Leary et al., 2015; Pascoe et al., 2017; Sanada et al., 2016). While evidence for practice-induced attenuation of acute cortisol reactivity primarily stems from laboratory studies (Engert et al., 2017; Lindsay et al., 2018; Morton et al., 2020), mental training studies investigating cortisol responses to naturalistic, daily-life stressors are still scarce (Aguilar-Raab et al., 2021).

It was thus a first aim of the current study to assess whether, and to which extent, the stress reducing effects of mental practice could be observed in individuals' daily lives. We employed ecological momentary assessment (EMA; Stone and Shiffman, 1994) to capture subjective and physiological (i.e., cortisol) stress markers in fixed intervals throughout participants' waking hours (see Methods section and Fig. 3 for details).

As a second aim, we were interested in participants' daily affective experience as well as thought patterns. Both have been shown to be salient dimensions of well-being and mental health (Fox et al., 2018; Fredrickson and Joiner, 2002; Ruby et al., 2013a) and common outcomes of mental practice (e.g., Fredrickson et al., 2017; Kok and Singer, 2017b). Accordingly, we repeatedly assessed individuals' first-person phenomenological experience regarding affect and arousal states as well as momentary thought content (Ruby et al., 2013a; Russel et al., 1989).

Following repeated calls to increase the ecological validity of findings in the realm of mental training and health research (Davidson and Dahl, 2017; Myin-Germeys et al., 2016; Sanada et al., 2016; Vieten et al., 2018), the experience sampling approaches allow for fine-grained insights into subjects' habitual everyday experience across various contexts, and in interaction with the external world (Shiffman et al., 2008). In comparison to retrospective methods, momentary assessments limit recall bias, and the influence of one's current state on single retrospective ratings (Trull and Ebner-Priemer, 2009), making them especially sensitive to the temporal fluctuations and situational specificity of many mental phenomena (Bishop et al., 2004; Lutz et al., 2002; Moore et al., 2016). As such, EMA approaches are an invaluable tool to explore how mental capacities, cultivated through repeated practice, are implemented into everyday life.

Among the current conceptual and methodological challenges in contemplative science (for critical commentaries see Dahl et al., 2015; Davidson and Kaszniak, 2015; Van Dam et al., 2017), a central theme is the frequent disregard of differences between practices, which often target distinct psychological processes (Chiesa and Malinowski, 2011; Dahl et al., 2015), and entail distinct phenomenological experiences (Brandmeyer et al., 2019; Lutz et al., 2007). Addressing this challenge, an overarching aim of the current study was the differential investigation of the effects of distinct types of mental training on daily life stress, thought content and affective states.

Our study was conducted in the context of the *ReSource Project* (Singer et al., 2016), a large scale, longitudinal investigation designed to disentangle the effects of mental training practices targeting attentional, socio-affective and socio-cognitive capabilities. These were practiced in three distinct modules termed Presence, Affect and Perspective. The *ReSource Project* recruited a large sample of thoroughly health-screened participants, who received mental training exceeding the typical eight weeks of mindfulness-based programs. The 3-month modules shared a similar structure: initial 3-day retreats familiarized participants with the respective core practices, which were subsequently trained in daily individual practice and weekly group sessions (at least 4.5 h per week, see Methods for details).

The Presence module specifically targeted attentional and interoceptive capacities through practice of the core exercises Breathing Meditation and Body Scan. It thus shared key characteristics with classical mindfulness-based interventions. Interoceptive awareness relates to the ability to attend to bodily sensations and mindfulness training has been associated with higher levels of relaxation (for reviews see Baer, 2003; Hölzel et al., 2011). Cultivation of present-moment awareness is another fundamental aim and main outcome of mindfulness interventions (Creswell, 2017; Hölzel et al., 2011) and the Presence module was specifically designed to train the ability to redirect attention to the present moment. In line with this initial hypothesis, subsequent *ReSource* findings focusing on questionnaire-based trait assessments (Hildebrandt et al., 2017) and acute practice effects (Kok and Singer, 2017b) showed a relative advantage of Presence training in fostering presence focus. Presence training was further found to be associated with comparably lower sympathetic arousal in another publication (Lumma et al., 2015).

The Affect module cultivated socio-affective capacities such as compassion, dealing with difficult emotions, acceptance and gratitude by means of (compassion-based) Loving-Kindness meditation and a dyadic contemplative exercise training socio-affective skills. These capacities are proposed to originate in a bio-social care system fundamental for affiliative behavior (for reviews see Gilbert, 2020; McCall and Singer, 2012). Compassion-based interventions have been suggested to particularly foster interpersonal processes, and increase positive affect (Hofmann et al., 2011; Klimecki et al., 2012). More recent meta-analytic evidence suggests that loving-kindness-based interventions improve well-being and social integration along with increased positive emotions (Galante et al., 2014; Zeng et al., 2015). Supporting the assumption of facilitated socio-affective functioning, recent *ReSource* findings show most effective attenuations of acute cortisol reactivity during psycho-social stress after Affect and Perspective training, while all modules reduced subjective stress reactivity (Engert et al., 2017). Further supporting the assumption of affective improvements, subsequent *ReSource* findings using micro-phenomenological, qualitative interviews (Przyrembel and Singer, 2018) and acute practice state effects (Kok and Singer, 2017b) showed most pronounced increases in positive affect after Affect training.

The Perspective module primarily targeted socio-cognitive skills such as meta-cognition and perspective-taking on self and others by means of Observing-Thought meditation and a dyadic exercise fostering interpersonal socio-cognitive capacities. Meta-cognition enables observing thoughts as mental events in a dis-identified way (Wells, 2005), and perspective taking further provides the means to detach and deconstruct social schemas to facilitate social interaction (Galinsky et al., 2005). In line with initially hypothesized effects, subsequent *ReSource* findings showed increased meta awareness of mental content after Perspective training in an acute pre- to post practice comparison (Kok and Singer, 2017b), and likewise increased feelings of social connectedness (Kok and Singer, 2017a). As mentioned above, attenuated acute stress and cortisol reactivity was also found after Perspective training (Engert et al., 2017).

1.1. Hypotheses

Based on the above literature we expected that the Presence training would most effectively strengthen participants' thought focus on the present moment and decrease daily life arousal.

We hypothesized that Affect training would be particularly effective in reducing both subjective and physiological stress levels and enhancing stress-coping. Further, we expected increased positive affective states as well as positive other-related thoughts specifically after Affect training.

In line with the notion that meta-cognition and perspective taking can improve daily social interaction, and additionally informed by the findings of reduced acute self-reported stress and cortisol levels to a psycho-social laboratory stressor within the *ReSource* sample (Engert et al., 2017), we expected similar effects of the Perspective module in daily life.

2. Methods

2.1. Participants

Participants of the *ReSource Project* (N = 332) were recruited in winter 2012/2013 in two major German cities (Berlin and Leipzig) and underwent comprehensive mental health screening, including structured interviews for DSM-IV axis I and II disorders (SCID-I DIA-X and SCID-II; First et al., 1997; Wittchen et al., 1997). Among the exclusion criteria were Axis-I disorders within the past 2 years, previous Axis-II disorders, medication intake affecting the HPA axis, and previous meditation experience. For a complete list of inclusion/exclusion criteria, and detailed information on the multi-step recruitment process as well as sample demographics of the *ReSource Project*, see chapter 7 in Singer et al. (2016) and the Supplementary Materials.

The participant sample at the starting point of the current study consisted of 289 healthy adults [172 women, mean ± SD = 40.6 ± 9.3 years, 20–55 years; also see Linz et al. (2018) and the Supplementary Materials for details]. 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 (ethic number: 376/12-ff) and Humboldt University Berlin (ethic numbers: 2013–20, 2013–29, 2014–10). Participants gave written informed consent, could withdraw from the study at any time, and were financially compensated.

A previous publication from the *ReSource Project* investigated momentary interrelations of subjective experience with cortisol levels at the study baseline, prior to the intervention (Linz et al., 2018). Data for the present analysis focusing on longitudinal, training-induced change in these measures were not part of any other publication. For a complete list of previous *ReSource* publications see the Supplementary Materials (Appendix).

2.2. ReSource training program

The *ReSource* training was specifically designed to capture the multifaceted and differential effects of distinct mental training modules on behavior, brain, and body. To this end, the training was divided into three separate training modules: Presence, Affect, and Perspective (Fig. 1). Each module started with a 3-day retreat, in which participants were familiarized with the modules' core exercises by professionally trained teachers. Subsequently, proficiency in the core exercises was further developed through guided practice in the presence of teachers (weekly 2-h group sessions). Additional solitary practice (individually for about 30 min daily) throughout the three months of each module was facilitated by a smartphone application or computer access to an online platform providing audio resources for each module. Regarding the module's main aims and core exercises, in the Presence module, participants trained attentional and interoceptive abilities through the core exercises Breathing Meditation and Body Scan. Here, directing attention towards the present moment is trained through redirecting attention to one's body or other current sensations (Mipham, 2003). Attentional stability then serves as a fundament for further practice in most contemplative traditions. The Affect module focused on socio-affective skills such as gratitude, loving kindness, and compassion, which were practiced through Loving-Kindness Meditation and an Affect Dyad. It also aimed at cultivating care and prosocial motivation and enhancing practitioners' ability to deal with difficult emotions (Gilbert, 2020; McCall and Singer, 2012). The Perspective module trained socio-cognitive skills such as perspective taking and meta-cognition through Observing-Thoughts Meditation and a Perspective Dyad. It targets cognitive fluidity by training to adopt a meta-perspective on one's thoughts and detaching or deidentifying with the notions of self and other (Wells, 2005).

Both the Affect and Perspective dyad were structurally similar 10-min dyadic practices, in which two randomly paired participants share their experiences with alternating roles of speaker and listener. The dyadic format was designed to foster interconnectedness by providing opportunities for self-disclosure and non-judgmental listening (Kok and Singer, 2017a; Singer et al., 2016). The dyads differed in the targeted affective and cognitive capacities: in the Affect dyad, speakers practiced acceptance of difficult emotions, and generation of positive emotions, while the partner practiced empathic listening without responding and judgement. In the Perspective dyad, the speaker described a previously experienced situation through the perspective of a previously identified 'inner part' relating to a personality aspect. The listener practiced perspective-taking (theory of mind) by inferring the active inner part of the speaker (Kok and Singer, 2017a). Further details on the development of the training modules and the general training design are described in Singer et al. (2016).

Participants were randomly assigned to two 9-month training cohorts (TC1, TC2), one 3-month training cohort (TC3), or the retest control cohort (RCC, consisting of RCC1 and RCC2, Fig. 2 and Supplementary Fig. S1). In detail, TC1 and TC2 started their training with the Presence module. They then underwent Affect and Perspective modules in alternating orders, thus serving as mutual active controls. TC3 underwent only a 3-month Affect module, which served as active control for the Presence module. RCC participants took part in all testing but no training activities (for further details see Singer et al., 2016, chapter 4 and the Supplementary Materials). Data was collected at T0 before initiation of the mental training and within the last weeks of every training period (T1-T3). In counterbalancing the order of the three modules in two training cohorts, and by employing a no-training retest control cohort, the design allowed for both active and passive control of training effects.

2.3. Procedures

For each measurement timepoint (T0-T3), participants chose the same two consecutive weekdays representative of their daily life routines for saliva- and experience sampling. Daily self-report data on subjective experience was collected using a customized mobile app. Adequate handling of the app and proficiency in self-administering saliva samples was ensured in an initial introductory training. On each of the two sampling days per testing timepoint (T0-T3), sampling started

Fig. 1. Training modules and respective processes cultivated by core exercises.

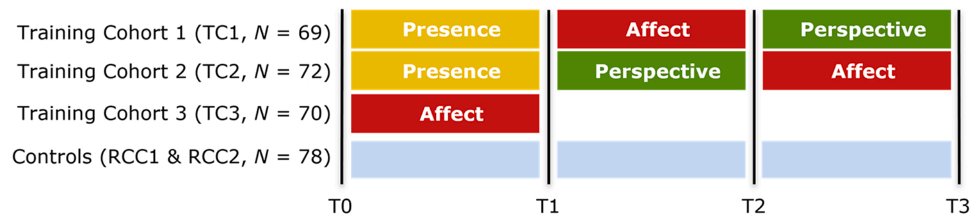

Fig. 2. Training sequence of training cohorts (TCs1-3) and retest control cohorts (RCCs) of the *ReSource* Project. N = participants per cohort atstart of the present study.

upon wakeup, and followed a time schedule in which samples of subjective experience were prompted six times in intervals of 120 min until 12 h after wake up (i.e., 120, 240, 360, 480, 600 and 720 min). Saliva was sampled immediately upon free awakening (while still in bed), and 30, 60, 240, 360, 480 and 600 min (see Fig. 3).

2.4. Measures

2.4.1. Subjective experience

At each probe throughout the day, participants provided ratings of momentary subjective experience on measures of thought content, affect and arousal, and the occurrence of stress, including a rating of stress intensity and individual coping success.

2.4.1.1. Thought content. Thought content at the time of sampling was operationalized using the 'cube of thought' (Ruby et al., 2013a). It characterizes the valence, temporal and social focus of current thoughts using three visual analogue scales, each ranging from 1 to 20 with written anchors at each pole. The valence scale ranged from 'negative' to 'positive', and the social scale from 'self-oriented' to 'other-oriented'. The temporal scale was used to indicate the extent to which thoughts were focused on the present moment. Therefore, to calculate a measure of "present focus", we extracted the relative distance to the scale's extremes (complete 'past'- or 'future'-focus) such that presence-focus ranged from 1 to 10 and was highest at the center point of the temporal scale (also see Engert et al., 2014).

2.4.1.2. Affect and arousal. The Affect Grid was used to measure current affect and arousal. Its single item scale assesses the dimensions pleasure-displeasure and arousal-sleepiness (both on a scale from 1 to 9). The Affect Grid has been shown to have adequate reliability, as well as convergent and discriminant validity (Russel et al., 1989).

2.4.1.3. Subjective stress and coping efficacy. At each sampling point, participants reported on the occurrence of a (concurrent or preceding) stressor in a yes/no format. If they had experienced a stressful event since taking their last sample, they additionally indicated how stressed they felt, and how successfully they were able to cope with the experienced stress (both on visual analog scales ranging from 1 to 20).

2.4.2. Physiological stress

Saliva for cortisol analysis was sampled using Salivette collection

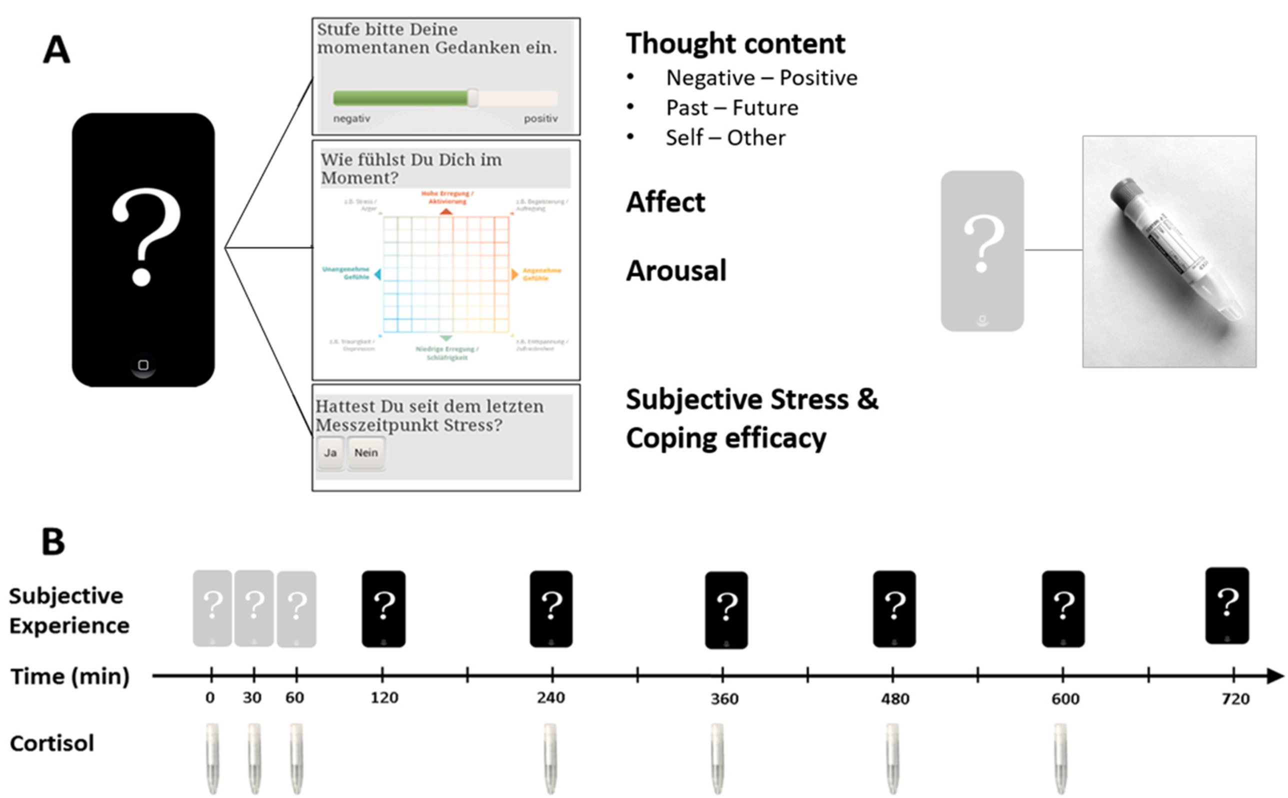

Fig. 3. Measures of subjective experience (A) and time schedule of these measures and salivary cortisol samples relative to wakeup (B). Prompts at wakeup, + 30 min and + 60 min represent saliva samples capturing the cortisol awakening response without concurrent assessment of subjective experience and did not enter analysis of stress-reactive cortisol levels.

devices (Sarstedt, Nümbrecht, Germany). Participants were instructed to place the collection swabs in their mouth for two minutes without chewing, and to refrain from any oral intake except water for 10 min prior to sampling. If deviating from this guideline, they were asked to thoroughly rinse their mouth with water before taking a sample. Participants otherwise followed their regular daily routines. Hormonal status (i.e., menopausal, using hormonal contraceptives, natural menstrual cycle, or male) was assessed to control for confounding effects on cortisol levels (Kajantie and Phillips, 2006). Salivettes were initially stored in participants' freezers. Once returned to the laboratory, they were stored at − 30 °C until assay (at the Department of Biological and Clinical Psychology, University of Trier, Germany). Cortisol levels (expressed in nmol/l) were determined using a time-resolved fluorescence immunoassay with intra-/interassay variabilities of < 10% / 12% (Dressendörfer et al., 1992). The current study focused on stress-reactive cortisol levels during participants' daily routines when encountering naturalistic stressors. We thus assessed cortisol levels combined with prompts on the occurrence (or absence) of stressors, as well as all other above mentioned measures of (stress) experiences, at four times during the day (at 240, 360, 480 and 600 min, see Fig. 3). Three initial morning samples captured the cortisol awakening response (CAR, taken at 0, 30 and 60 min after waking), which is considered a unique facet of diurnal cortisol output (Clow et al., 2010). These samples (captured without simultaneous assessments of subjective experience) were not included in the current analyses.

2.5. Statistical analysis

Significance level for hypothesis testing was set at $\alpha \leq 0.05$, unless adjusted for multiple comparisons and stated otherwise. Analyses were carried out using R (Version 4.0.2; R Core Team, 2020). To account for skewedness, cortisol data was ln-transformed prior to analysis. Analyses investigated differential module effects on each dependent measure individually. In detail, change in dependent measures was analyzed using hierarchical linear mixed models (LMMs) accounting for the nested data structure of repeated measures per day and testing timepoint (T0-T3) for each subject. Models were fit using the R package "lme4" (Bates et al., 2014), and the functions 'lmer' and 'glmer' were used for continuous/binary dependent variables. For each variable, we initially modeled an interaction term of training cohort and time in order to test whether dependent measures differed as a function of training routine over time (full model). These models were compared with models including only main effects of training cohort and time, but stripped of the interaction term (reduced model), by means of likelihood ratio tests (Dobson and Barnett, 2018). Models were compared with maximum likelihood estimation (MLE). Significance levels for model comparisons were lowered using Benjamini and Hochberg (2000) false discovery correction with FDR = 0.05. If models revealed a significant interaction effect, follow-up contrasts of model estimates tested for differences between modules and timepoints using the r package "lsmeans" (Lenth, 2016). Multilevel models implicitly address multiple comparison issues by performing partial pooling. Therefore, significance levels for contrasts were not additionally corrected (Gelman et al., 2012). More detail on the statistical approach including model specifications and diagnostics is provided in the Supplementary Materials (1.3).

3. Results

Descriptive statistics of all dependent variables per cohort and measurement timepoint are reported in Table S1 in the Supplementary Materials (2.1).

3.1. Effects of mental training

3.1.1. Model selection

Full- vs. reduced model comparisons for all dependent variables are depicted in Table 1. Full models provided a significantly better model fit when, over time, differences in dependent variables were detected between cohorts [i.e., training cohorts (TCs) and retest control cohort (RCC)]. Significantly better model fit for full models was found for arousal, affect, valence of thought content, temporal thought content, as well as stress and stress-coping. Non-significant interactions between timepoint and cohort indicated a better fit of the reduced model, which separately investigated main effects of time (i.e., retest effects) and mean differences between cohorts not attributable to training duration. Reduced models were fit to the variables social thought content, stress intensity and stress-reactive cortisol levels.

3.1.2. Follow-up contrasts

To investigate training effects in detail, follow up contrasts were conducted in all significant full models. Contrasts compared dependent variables per time-point and cohort, and primarily focused on within-cohort changes attributable to the respective modules trained. Significant differences between TCs and RCC were found for arousal, temporal thought content (presence-focus) and stress-coping, see Fig. 4. All contrasts are detailed in the Supplementary Materials.

3.1.2.1. Arousal. In contrast to the RCC, which did not show significant change in arousal over time, both TC1 and TC2 showed significant increases in arousal from the pre-intervention baseline (T0) to the post-intervention testing time-point at 9 months (T3). These time-dependent training effects - both Affect and Perspective module drove change from 3 to 6 months into practice - were consistently found at 6 months of practice, and remained stable afterwards.

3.1.2.2. Presence-focused thought. In contrast to the RCC, presence-focus of thoughts consistently increased after three months of training in all training cohorts (after the Presence module in TC1 and TC2, and after the Affect module in TC3). In TC1 and TC2, Presence-focused thoughts remained elevated after six months of training (compared to baseline) and subsequently regressed back to the mean.

3.1.2.3. Stress coping. In contrast to the RCC, for which stress coping significantly declined from T0 to T3, there was a significant increase in self-reported coping success after six months of training in TC2, and after nine months of training in TC1. In both cohorts, these changes were driven by the Perspective module. Additional contrasts of within-cohort changes from T1 to T3 by module revealed a significant difference between the Perspective module and both other modules (Affect and No training; $t(1606) = 2.03$, $p = .021$).

Table 1
Full-/reduced-model comparisons with chi-square test statistic and model selected. Significance levels were adjusted for multiple testing via Benjamini and Hochberg (2000) correction with FDR = 0.05 for 9 tests; * indicates significance after p level adjustment. DV, dependent variable; p crit, p level after correction.

DV	$\chi2$	df	p	Rank; p crit	Model selected
Arousal	22.385	7	0.002 *	3; 0.016	Full
Affect	16.035	7	0.024 *	6; 0.033	Full
Thought content					
Valence (negative – positive)	16.839	7	0.018 *	5; 0.027	Full
Temporal (past/future – presence)	7287.9	7	< 0.001 *	1; 0.005	Full
Social (self – other)	12.524	7	0.0846	7; 0.038	Reduced
Stress					
Stress event (y/n)	23.45	7	0.001 *	2; 0.011	Full
Stressor intensity	4.5758	7	0.712	8; 0.044	Reduced
Stress Coping	20.992	7	0.004 *	4; 0.022	Full
Stress-reactive cortisol levels	3.2883	7	0.857	9; 0.05	Reduced

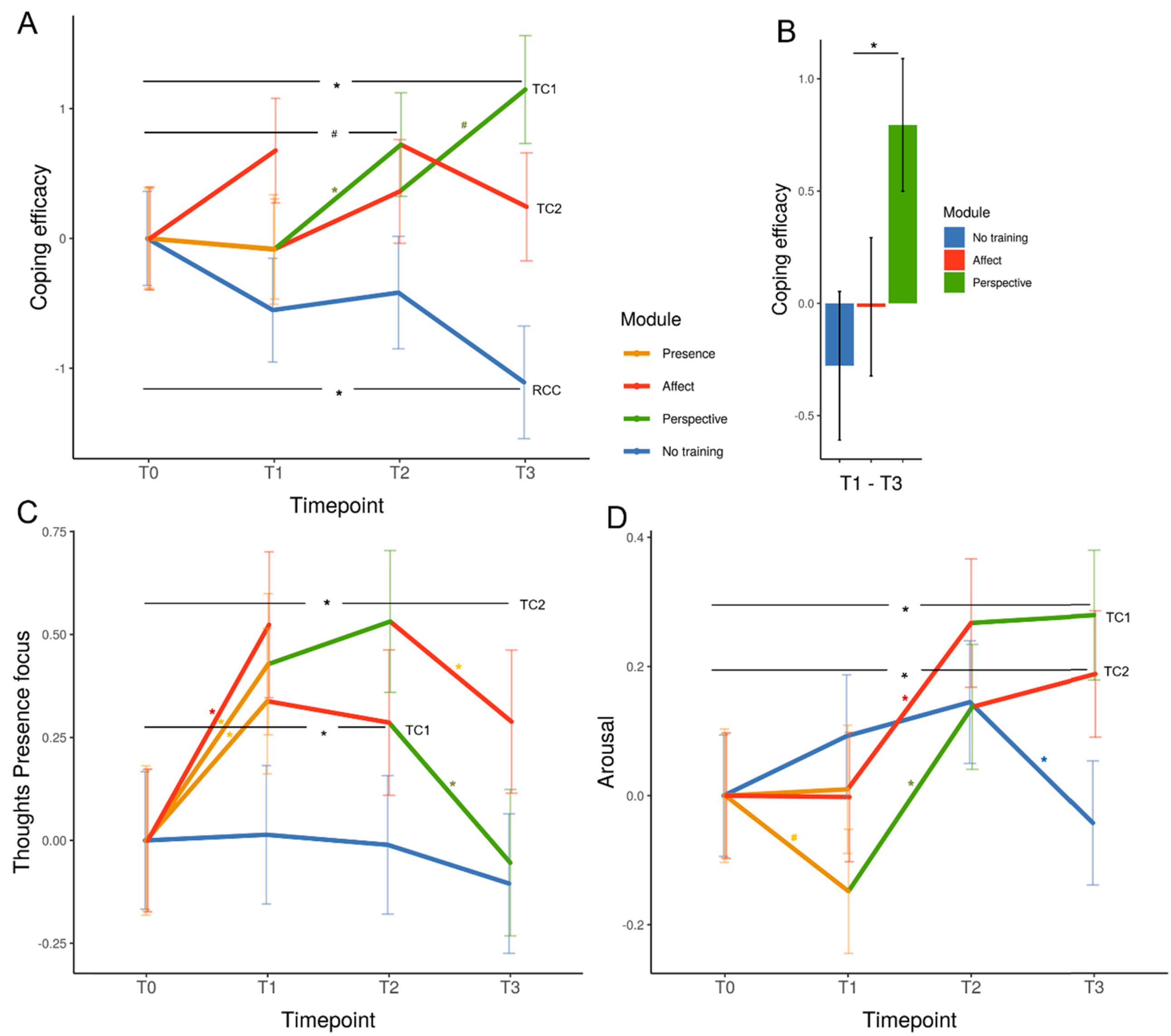

Fig. 4. (A, C, D) Model estimates (z scores relative to cohort baseline) and contrasts for training effects on Arousal, Presence-focused thought, and coping efficacy. Error bars depict SEM; * , significant follow-up contrast (p < .05); #, p < .01. (B) Average contrasts (+/- SEM) in coping efficacy from T1 -T3 for each module.

3.1.2.4. Non-significant contrasts. Investigating contrasts of the remaining full- models revealed only retest effects. In brief, we found retest effects in all cohorts for affect and valence of thought content (significant reductions in both positive thoughts and positive affect from pre- to post intervention in all cohorts). Reports of stressful events were significantly reduced in all cohorts after 9 months (no change after 3 months in TC3).

Last, reduced models showed no significant interactions between cohort and time (and thus no training effects) for the measures social thought content, stress intensity and stress-reactive cortisol levels. Model summaries are presented in the Supplementary Materials.

4. Discussion

A key question in studying effects of meditation-based mental training interventions regards the extent to which the trained mental states and capacities carry over to everyday life. The present study consequently assessed the impact of three different types of meditation-based mental training (attentional, socio-affective and socio-cognitive) on daily-life experience. In detail, we captured affective states, thought content, stress-related experiences and coping as well as diurnal cortisol release. Using an EMA approach with high granularity and ecological validity, we pursued three goals: First, we tested whether previously observed lab-based mental training effects on stress reactivity would replicate in the context of individuals' everyday routines. Second, we tested whether mental training could alter everyday affective states and thought content similarly to lab-based observations or acute practice effects. Third, we investigated differential effects of different types of mental training on our respective outcomes. We had several module-specific hypotheses based on previous literature and earlier findings from the *ReSource Project*, the longitudinal large-scale mental training project the present study was embedded in (Singer et al., 2016).

We found training-induced changes in selected facets of daily-life experience: Arousal, present-moment focus of thoughts, and coping efficacy with everyday stress were increased after three to six months of practice duration. Two of these effects developed independent of training content, either over time (i.e., arousal), or as an initial consequence of training (i.e., presence focus of thoughts). Perceived coping efficacy with everyday stress was enhanced specifically after the Perspective module, and emerged independent of training duration (i.e., after 3 months or 6 months of the training program). In the following discussion of our significant and non-significant findings, we first focus on all stress-related measures. Subsequently, findings on affect, arousal and thought content are discussed.

4.1. Subjective stress, stress-coping, and cortisol

In line with our hypothesis, we found that mental training led to more successful coping with daily life stress. Other than expected, this effect was specific to Perspective training, and was not observed after Affect training. Also contrary to our expectations, neither the amount of reported daily-life stressors nor subjective stress experience in response to those stressors were lowered by training. This outcome also contrasts recent EMA findings after relatively shorter mindfulness-based interventions (Chin et al., 2019). Thus, our results suggest that mental training does not reduce the exposure to daily life stressors (i.e., their occurrence and intensity) per se. Rather, cultivating skills such as meta-cognition and perspective-taking seems to improve how well individuals feel they can handle the stressors at hand. In training the ability to view challenging daily life experiences from different perspectives (or inner parts), the dyadic exercise implemented in the Perspective module may target a particularly valuable coping resource. By teaching to take on the perspective of others and how inner personality aspects color one's daily interactions and experiences, it may lead to a more distanced outlook, and the understanding that adversities (as well as maladaptive thoughts and emotions) come and go. These capacities would assist effective coping with social stressors encountered in daily life. Previous laboratory findings showed that, together with the Affect module, the Perspective module was most efficient in reducing both subjective stress and cortisol reactivity to an acute psychosocial stressor (Engert et al., 2017). At least after Perspective training, enhanced coping skills may have contributed to these effects.

Discrepancy between our results and retrospective accounts of subjective stress levels, in which we previously found no reduction (e.g., Puhlmann et al., 2021; reporting perceived stress in the last month), are likely methodology-based. By teasing apart the occurrence of stressors, subjective stress levels and coping efficacy, and by repeatedly probing these constructs on a momentary basis, the current results provide a nuanced picture of participants stress experience throughout their daily lives. In particular, the EMA methodology circumvents the pitfalls of retrospective methods, which may be more prone to confound stressor, stress load and coping success in hindsight, due to attention- or recall biases (Trull and Ebner-Priemer, 2009; Uttl and Kibreab, 2011). Corroborating this view, other studies using EMA methods suggest differences between momentary and retrospective assessments of stress or stress-related subjective states (Chin et al., 2019; Moore et al., 2016).

The current findings also differ from previous training studies reporting reduced subjective stress levels in acute laboratory stress settings (for a recent review see Morton et al., 2020). This includes our own findings in the same participant sample, showing module-unspecific buffering of subjective stress reactivity after three or six months of practice (Engert et al., 2017). We argue that the current findings should be viewed as complementary rather than conflicting evidence: Stress responses to a standardized, pronounced, and transient laboratory stressor certainly differ in both quality and quantity from most stressors encountered in everyday life. Those tend to be less marked, but more frequent and potentially of longer duration or recurring (Epel et al., 2018; Linz et al., 2018).

Methodological discrepancies between studies likely also contribute to inconsistent findings in cortisol levels. Contrary to our hypothesis, no evidence for training-induced attenuation in cortisol release during everyday stress experience was detected. Our hypothesis was primarily based on laboratory work (Engert et al., 2017). Although few other laboratory studies have shown reduced cortisol reactivity to psychosocial stress after mindfulness training (and several failed to find effects; Morton et al., 2020), no study has yet demonstrated comparable effects in response to naturalistic stressors. This gap likely stems from the challenges inherent to measuring cortisol levels in daily life settings, where the predominant share of variance in cortisol levels can be attributed to natural variation in diurnal cortisol rhythm (Kudielka et al., 2012). Additional variance is introduced by multiple mundane actions, such as dietary intake and the general level of (physical) activity (see limitations below for a more detailed discussion). Given the relatively subtle immediate impact of daily hassles, effects of mental training on daily cortisol levels may have been masked. We argue that cumulative measures like hair cortisol concentration may be less sensitive to such variance, explaining our divergent results in an earlier *ReSource* study (Puhlmann et al., 2021). Supporting this assumption, meta-analytic evidence highlights that the manner in which cortisol is measured is one of the key methodological differences accounting for inconsistencies between studies exploring mental training effects on physiological stress markers (Koncz et al., 2021). Stronger reductions were found when investigating at-risk populations (i.e., patients or high-stress individuals), and when employing blood cortisol (O'Leary et al., 2015; Pascoe et al., 2021, 2017; Sanada et al., 2016). Lower effects were reported for randomized controlled trials investigating healthy subjects' salivary cortisol levels (Koncz et al., 2021).

The current and previous *ReSource* findings underline the complexity of researching stress, and its dependency on the manner in which stress is measured: Assessing stress and cortisol employing either an acute laboratory stressor (Engert et al., 2017) or retrospective self-reports and hair cortisol (Puhlmann et al., 2021) revealed varying mental training effects in the same set of *ReSource* participants – depending on the measured timeframe (spanning hours, days, or months), setting (laboratory or real life) or specimen (saliva or hair). Corroborating evidence suggests methodological specificity and a complex structure of stress and its various measures already at the pre-intervention baseline (Engert et al., 2018). As such, it is important to view these results as addressing complementary research questions, yet with varying foci on this intricate field of research. While in the current study, improved coping was not mirrored in concurrent (acute) cortisol reductions, subjectively improved coping success may in the long run nevertheless contribute to a reduced emotional and physiological stress load, especially if training is extended beyond three months of duration (Puhlmann et al., 2021).

The present findings further add to a growing body of research suggesting that especially high-stress and clinical populations profit from cortisol attenuations after mental training (Koncz et al., 2021). In this light, we cannot exclude the possibility that – in healthy individuals – even extended training periods may not significantly impact cortisol levels in response to daily life stressors. Future studies in at-risk and patient populations, along with studies investigating individual differences in other health-related measures will help identify those individuals who, in terms of diurnal cortisol release, may profit most from contemplative training.

4.2. Presence focus, arousal and affect

With regard to our second aim, we found the expected increase in present-moment thought focus after the 3-month training of attention and interoceptive awareness in the Presence module. However, similar reductions were found after three months of Affect training (in TC3), suggesting an unspecific initial training effect rather than a specific consequence of the Presence training. The detected pattern converges with, and adds ecological validity to, previous self-report data showing strongest increases in trait presence-focus after both Presence and Affect modules (Hildebrandt et al., 2017). Also, comparing immediate pre- to post-practice states revealed that Presence training lead to the greatest decrease in general thought amount and most efficiently fostered presence-focus (Kok and Singer, 2017b). Overall, our data suggest that alterations in daily life thinking styles, in particular a stronger anchoring in the present moment, can be achieved through three months of regular mental practice.

Last, we found consistent and stable increases in daily life arousal after 6 months of practice. The initial three months of training (independent of whether practicing Presence in TC1 and TC2, or Affect in TC3) did not raise arousal levels. Subsequently, arousal increased after both Affect and Perspective training, and this increase persisted after nine months of training in both cohorts. Contrary to the popular belief of meditation always being relaxing, facilitating states of wakefulness is a common and desired outcome of many Buddhist practices (Britton, 2014). Along those lines, Lumma and colleagues (2015) showed in another *ReSource* publication that both Loving-Kindness meditation (Affect module) and Observing-Thoughts meditation (Perspective module) were experienced as more effortful than Breathing meditation (Presence module). Also, sympathetic arousal was relatively increased for Affect and Perspective core meditations compared to Presence (Lumma et al., 2015). While our data revealed a corresponding pattern with increases in arousal after 6 months of Affect and Perspective training, it should be noted that the observed enhancements in arousal may well have adaptive qualities for daily tasks.

Several differential a priori hypotheses remained unconfirmed. In particular, we had expected advantages of the Affect module in fostering positive affect in daily life. Our expectation was based on findings of increased daily positive emotions after loving-kindness and compassion-based interventions (Zeng et al., 2015). Previous *ReSource* findings further showed increased positive emotions and feelings of warmth as an acute practice effect of loving-kindness meditation (Kok and Singer, 2017b), and a similar pattern of increased positive emotions in retrospective interviews (Przyrembel and Singer, 2018). The discrepancy between the present and previous studies regarding training effects on positive affect should primarily sensitize for the different temporal foci. Unlike the above-mentioned findings of acutely boosted positive affective states or retrospective increases in positive emotions associated with Affect training, the present data suggest that none of the modules could significantly increase the (already quite positive) everyday affective states of the current healthy adult sample. As such, our findings also contrast with reports of increased positive affect after mindfulness-based interventions (Enkema et al., 2020). Further, contrary to previous findings and hypotheses, Affect training did not increase positive, other-directed thought patterns in daily life. Together, our data suggest that for some domains of subjective experience, the acute practice effects revealed by comparing pre- to post practice states are difficult to replicate when sampling mental experience over a broad range of activities and contexts during participants' daily routines.

4.3. Limitations

Several limitations of the present study need to be addressed. First, ambulatory assessment of cortisol is associated with large shares of unaccounted variance. While we attempted to limit and control for major influences on cortisol levels arising from food/beverage intake or physical exercise by instructions and through statistical analyses, improved compliance to the sampling protocol and punctuality could have been ascertained with additional control instances (e.g., time-stamped cortisol capsules or photographic evidence). On the same note, only self-initiated participant assessments of stressor occurrence and accordingly time-lagged cortisol assessment would have allowed precise estimation of stress-reactive cortisol levels. However, in order to keep daily routines as natural as possible in an EMA design, we chose to not impose additional sampling duties on participants (also see Linz et al., 2018 for a more detailed discussion of methodological limitations). Second, while the comprehensive screening procedure of the *ReSource Project* certainly adds to the study's strengths, it may also have led to an overly healthy and homogeneous sample, ranging above-average in socio-economic status. We thus need to be cautious in generalizing the present findings to vulnerable or patient populations, especially since participant health status is a decisive factor for inconsistently reported salutogenic effects in contemplative science (Black and Slavich, 2016; Pascoe et al., 2017). Third, only a fully counterbalanced design exploring all possible permutations of modules and timepoints would have allowed for complete statistical separation of time, sequence and module effects. Finally, while the counterbalanced modules can serve as active controls for each other, only an additional training cohort starting with the Perspective module would have allowed complete comparison of isolated effects of all modules.

4.4. Conclusion

Along with the immense interest in meditation-based mental training programs, and the increasing number of studies suggesting beneficial effects on stress and associated subjective experience, research has identified several challenges in the field of contemplative science. Next to greater awareness of the differences between practice types and interventions, increasing the ecological validity of findings is a necessary step to advance the field – and to avoid inflated expectations of what mental practice can actually achieve in one's everyday life.

The current study aimed at addressing these challenges by employing fine-grained assessments in a naturalistic setting to differentially investigate the effects of the three training modules implemented over nine months in the *ReSource Project* (Singer et al., 2016). Together, our findings show that sustained practice exceeding three months of training duration is necessary for the emergence of measurable daily-life improvements of important mental skills, such as enhanced stress-coping efficacy. Our study adds complementary evidence to investigations of immediate state effects following acute mental practice, and to investigations employing self-reports and more stationary (e.g., laboratory-based) measurements of training effects. While effects in the current naturalistic setting were comparably lower in size and less clear-cut, they corroborate and add ecological validity to previous *ReSource* findings, for example by illustrating the modules' distinct effects on daily life arousal and presence-focus. At the same time, as in the case of stress and associated cortisol levels, our results highlight the fact that findings from the laboratory do not necessarily generalize to the outside world, and that the methodological heterogeneity of mental training studies poses an obstacle in the synthesis of results (Goyal et al., 2014; Van Dam et al., 2017). Overall, by targeting training-induced change in a range of psycho-physiological stress markers and mental states in real life, the current study provides an important step in the understanding of how contemplative mental training can limit the cost of stress by transforming daily experience to improve wellbeing and sustain healthier lives.

CRediT authorship contribution statement

T.S. initiated and developed the *ReSource Project* and model as well as the training protocol and secured all funding. V.E. and T.S. designed the study protocol. R.L., L.P. and V.E. were involved in data assessment and analysis. R.L. designed the statistical models, L.P. contributed to statistical approach and figures. R.L. and V.E. drafted, and T.S as well as all other co-authors contributed to writing the manuscript and approved its final version for submission.

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Conflict of interest statement

The authors declare that they have no conflict of interest.

Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.psyneuen.2022.105800.

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