

Error Processing and Mindfulness Meditation in Female Students: Supplementary Material

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1. Methods

1.1 Justification for experimental design and control group

First, mindfulness meditation training will be given to a group of novices to avoid the detrimental effects of a cross-sectional study when comparing long-time meditators with novices. Group differences could not only be due to meditation, but also to differences in lifestyle, spirituality, social relationships and so forth. Second, to control the general effect of relaxation (Schwartz, Davidson, & Goleman, 1978), we compared the experimental group with an active control group practicing *progressive muscle relaxation* (PMR), a physical relaxation method with a focus on the reduction of physiological arousal on various levels by alternating tension and relaxation of different muscular groups (Lehrer, 1982; Schwartz et al., 1978). Therefore, PMR does not directly address cultivation of mindful awareness with an emotional accepting attitude. To avoid teacher-specific effects, we used audio trainings of smartphone applications with the same specialized instructions for each participant. Finally, a smartphone-controlled training could be easily integrated in the daily life of our student sample.

1.2 Description of interventions

All participants received practice instructions (written and oral) and a practice record log and were requested to record the date, time, and duration of training into the log. Those in the meditation group were also instructed to note if and when they changed from guided to silent meditation. The author e-mailed each participant four times (once each week, including a reminder the day before Session 2) to encourage the maintenance of daily practice, to offer advice, and to ask about any problems during the training. Responses to any questions were given individually via e-mail. After their participation, the participants received the audio data or smartphone application of the other group and they were debriefed about the purpose of the study.

Progressive Muscle Relaxation. The participants were provided with two different versions of PMR, a short version of 17 minutes and a long one of 32 minutes (Techniker Krankenkasse, 2013). They were asked to perform at least twice-daily home practice sessions for the four weeks of training, with at least the short version. It was recommended to increase the training amount if possible. The short version started in a relaxed position, with the participants closing their eyes and breathing in own rhythm for a short time. The task began subsequently, by mildly contracting the muscles of the arms by making fists, and afterwards relaxing these body parts. Successively, the muscles of head, brow, neck and jaw, shoulders, feet and legs should be contracted and relaxed. After the task, the relaxation should be felt by focusing on and deepening the breath. The goal would be to encourage a focus on the body with relaxation of every body part. The last part of the practice was accompanied by calm music where participants were encouraged to imagine pictures, listen to the music, or focus on the breath. The session ends with a stretch and then opening the eyes.

The long version was similar to the short version, but with more differentiation between the body parts being contracted and relaxed: right hand, right upper arm, left hand, left upper arm, brow, eyes, nose and cheeks, lips, jaw, right and left side of the neck, nape, shoulders, back, abdominal muscles, gluteal muscles, right thigh, right calf muscle, right foot, left thigh, left calf muscle, left foot.

Mindfulness Meditation. The smartphone application consisted of several audio files of several lengths (3, 5, 15 and 30 minutes), in guided and silent versions (MindApps, 2013). The participants were asked to keep training for the four weeks at least twice-daily, with at least the 15-minutes guided meditation. It was recommended to increase the training amount if possible and switch to the silent meditation when they were accustomed to the content of the meditation, as a silent meditation may exercise a greater degree of autonomy versus a former dependency on the rigid practice. The 15-minute version starts with focus of attention inwards and by

observing the present moment without changing the experience. Then it continues with focused attention on the breath with a stance of curiosity and openness, encouraging a non-judgmental perspective on emerging thoughts. The breath serves as anchor of the here and now. During the meditation, there is a short focus switch towards body sensations or pain with a friendly, open stance. The session ends with focus on the body as a whole, and then, the focus on the breath is repeated. The 30-minutes version (MindApps, 2013) starts with a body scan, followed by focused attention on the breath. Afterwards, the focus should be on the surrounding sounds and later on thoughts and sensations without judging them. Thoughts should be observed as “leaves on a river while sitting at the bench”. The session ends with a period of open presence and finally, the focus on the breath is repeated.

1.3 Experimental paradigm

The participant's task depended on the color of the framed boxes. In the white condition (position), the participant had to respond to the position of the arrow (shown in the right or left box), disregarding its direction. In the cyan condition (direction), the participant had to respond to the direction of the arrow (either left: <; or right: >), while ignoring its position. In each trial, the two boxes were first filled with a white noise distributed dot pattern (mask) for 200 ms; then an arrow (either > or <) was shown in one of the boxes. Equally randomized between the blocks, the arrow was presented at 84 ms. The mask was presented again (for 216 ms). In the position condition (white), the boxes were empty for 350 ms, followed by a feedback (the frame turned red for 367 ms) if the RT was slower than 550 ms. In the direction condition (cyan), the empty boxes were presented for 1600 ms, followed by a detection task, in which the German words richtig + falsch [correct + wrong] were presented for 1000 ms (horizontal visual angle: 3.24°, white font color on black screen) and the participant had to decide whether the previous response was correct or incorrect. A blank screen followed for 417 ms and the next trial started

1.4 Details of apparatus

We used a strain gauge attached on the fixed end of a leaf spring (4.33 x 0.75 x 0.08 inches) held by an adjustable clamp at one end of the key, while the participant pressed the free end. Hence, an analog electrical signal corresponding to the applied force was produced for each key depression. This signal was recorded for 2000 ms at a sampling rate of 500 Hz, starting at the onset of the visual response signal. To maintain a constant position and a distance of 23 inches from the computer screen, a chin rest was used.

1.5 Signal Detection Theory

The four response types (detected errors, undetected errors, false alarms, correct trials) can be interpreted using signal detection theory (SDT; Green & Swets, 1966), where the detected errors are classified as “hits”. Hence, the decision criterion c (response bias; a high score indicates fewer false alarms and more undetected errors) and the sensitivity d' (a high score indicates more readily error detection) were analyzed as follows:

$$c = -0.5 \cdot [z(\text{hit rate}) + z(\text{false alarm rate})],$$

$$d' = z(\text{hit rate}) - z(\text{false alarm rate}),$$

where the function $z(p)$, $p \in [0,1]$, is the inverse of the cumulative Gaussian distribution.

1.6 EEG specifications

Scalp electrodes: FP1, FP2, AF7, AF3, AF4, AF8, F7, F5, F3, F1, Fz, F2, F4, F6, F8, FT7, FC5, FC3, FC1, FCz, FC2, FC4, FC6, FT8, T7, C5, C3, C3', C1, Cz, C2, C4, C4', C6, T8, TP7, CP5, CP3, CP1, CPz, CP2, CP4, CP6, TP8, P7, P5, P3, P1, Pz, P2, P4, P6, P8, PO7, PO3, POz, PO4, PO8, O1, Oz, O2.

Vertical and horizontal electrooculograms (EOG) were recorded from electrodes placed supra- and infraorbital to the left eye, and 0.79 inches lateral from the outer canthi.

A current source density analysis (CSD) is the Laplace-transformed ERP waveform, which were computed for each electrode site by taking the second derivative of the distribution of the voltage over the scalp (Perrin, Bertrand, & Pernier, 1987; Perrin, Pernier, Bertrand, & Echallier, 1989; Pernier, Perrin, & Bertrand, 1988). This made the signal independent of the location of the reference electrode as different reference locations can affect the ERP signal differentially (Luck, 2014), but not the CSD signals.

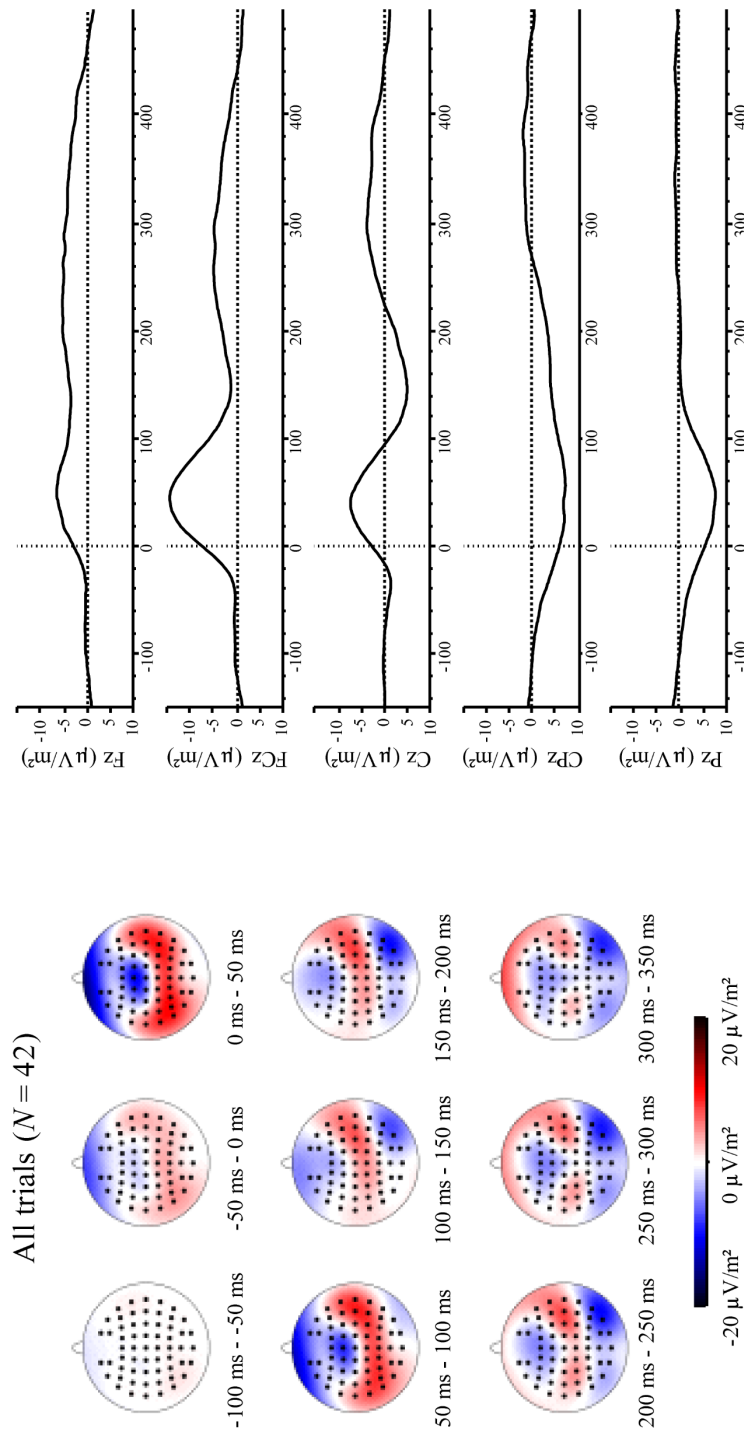


Figure S1. Brain mappings for the averaged time range of -100 – -50, -50 – 0, 0 – 50, 50 – 100, 100 – 150, 150 – 200, 200 – 250, 250 – 300 and 300 - 350 ms and current source density response-locked event related potentials ($\mu\text{V}/\text{m}^2$) at Fz, FCz, Cz, CPz and Pz for all trials (detected and undetected correct and erroneous trials combined over $N = 42$). Response onset is at 0 ms. Negative is plotted up

2. Validity Check

To check internal validity, we calculated both Pearson's correlations between all questionnaire scores of Session 1 and Pearson's correlations between their change scores of all questionnaires (calculated difference between posttest and pretest scores). The means and standard deviations (SD) of the questionnaire scores for all participants of both sessions and the correlation coefficients of Session 1 are presented in Table S1. The correlations between FFA and both PHLMS factors are significant (awareness: $r = .577, p < .01$; acceptance: $r = .402, p < .05$). Only the acceptance factor correlates negatively with ASS-SYM ($r = -.574, p < .001$). There is no other significant correlation (for all r s, p s $> .10$). Table S1 also shows the correlations of change scores. An increase in FFA correlates with a positive change in awareness ($r = .341, p < .05$), acceptance ($r = .700, p < .01$), and stress reduction ($r = -.529, p < .001$). An increase in awareness accompanies a positive change in acceptance ($r = .442, p < .01$) and in stress reduction ($r = -.376, p < .05$). An increase in acceptance is strongly related to stress reduction ($r = -.633, p < .001$).

Supplementary Material: Table S1

Means and standard deviations (SD) of the assessed questionnaire pre- (T1) and post-training (T2) scores, correlation coefficients of T1 and of change scores (T2-T1) (above the diagonal) for the entire sample

Measure (T1/ Δ_{T2-T1})	Correlation coefficients							
	mean _{T1}	SD _{T1}	mean _{T2}	SD _{T2}	1	2	3	4
1. FFA	1.86	0.48	2.01	0.43	-	.341*	.700**	-.529***
2. PHLMS awareness	3.59	0.51	3.79	0.63	.577**	-	.442**	-.376*
3. PHLMS acceptance	3.05	0.79	3.35	0.76	.402**	.019	-	-.633***
4. ASS-SYM	50.19	16.66	36.14	17.31	-.288	.066	-.574**	-

Note. $N = 42$.

FFA = Freiburger Fragebogen zur Achtsamkeit

PHLMS = Philadelphia Mindfulness Scale

ASS-SYM = Änderungssensitive Symptomliste zu Entspannungserleben, Wohlbefinden, Beschwerden- und Problembelastungen

* $p < .05$, ** $p < .01$, *** $p < .001$

Supplementary Material: Table S2

Group means (standard error of means, SEM) of questionnaire scores for pre- and post-training, statistics for change scores separated by group (Meditation versus Progressive Muscle Relaxation, PMR) (p)

		Pre (<i>SEM</i>)	Post (<i>SEM</i>)	Δ_{T2-T1} (<i>SEM</i>)	$p_{\Delta T2-T1}$
FFA	Med	1.99 (0.10)	2.11 (0.09)	0.12 (0.09)	.175
	PMR	1.72 (0.10)	1.90 (0.09)	0.18* (0.09)	.050
PHLMS awareness	Med	3.69 (0.11)	3.91 (0.13)	0.22 (0.11)	.050
	PMR	3.48 (0.11)	3.67 (0.14)	0.19 (0.11)	.110
PHLMS acceptance	Med	3.16 (0.17)	3.43 (0.16)	0.27 (0.14)	.052
	PMR	2.93 (0.18)	3.26 (0.17)	0.32* (0.14)	.031
ASS-SYM	Med	47.46 (3.54)	34.82 (3.72)	-12.64** (3.60)	.001
	PMR	53.20 (3.71)	37.60 (3.91)	-15.60** (3.78)	.001

Note. Meditation: $N = 22$; PMR: $N = 20$.

FFA = Freiburger Fragebogen zur Achtsamkeit

PHLMS = Philadelphia Mindfulness Scale

ASS-SYM = Änderungssensitive Symptomliste zu Entspannungserleben, Wohlbefinden, Beschwerden- und Problembelastungen

* $p < .05$, ** $p < .01$; *** $p < .001$; Bonferroni corrected.

Supplementary Material: Table S3

Session (pre- vs. post-training) x Group (Meditation versus Progressive Muscle Relaxation, PMR) – General Linear Model of questionnaire scores, evaluation of the effect sizes according to Cohen (1988)

Factor	Questionnaire	$F(40,1)$	p	η^2	90% $CI \eta^2$	Evaluation
Session	FFA	5.850	.020	.128	[.011; .287]	Medium effect
	PHLMS awareness	6.640	.014	.142	[.017; .303]	Large effect
	PHLMS acceptance	9.023	.005	.184	[.030; .333]	Large effect
	ASS-SYM	29.236	.000	.422	[.198; .539]	Large effect
Group	FFA	4.114	.049	.093	[.000; .238]	Medium effect
	PHLMS awareness	2.181	.148	.052	[.000; .185]	Small effect
	PHLMS acceptance	0.829	.368	.020	[.000; .134]	Small effect
	ASS-SYM	0.870	.357	.021	[.000; .136]	Small effect
Session x Group	FFA	0.264	.610	.007	[.000; .099]	No effect
	PHLMS awareness	0.045	.833	.001	[.000; .044]	No effect
	PHLMS acceptance	0.057	.812	.001	[.000; .055]	No effect
	ASS-SYM	0.322	.574	.008	[.000; .104]	No effect

Note. Meditation: $N = 22$; PMR: $N = 20$.

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3. Behavioral error data

Supplementary Material: Table S4

Session (pre- vs. post-training) x Group (Meditation versus Progressive Muscle Relaxation, PMR) – General Linear Model of behavioral error data (post-error slowing, post-error performance and total error rate), evaluation of the effect sizes according to Cohen (1988)

Factor	Outcome	$F(40,1)$	p	η^2	90% CI η^2	Evaluation
Session	Post-error slowing	1.277	.265	.031	[.000; .155]	Small effect
	Post-error performance	34.122	.000	.460	[.261; .590]	Large effect
	Total error rate	26.238	.000	.396	[.175; .518]	Large effect
Group	Post-error slowing	0.705	.406	.017	[.000; .128]	Small effect
	Post-error performance	0.853	.361	.021	[.000; .135]	Small effect
	Total error rate	0.002	.969	.000	[.000; .002]	No effect
Session x Group	Post-error slowing	0.063	.802	.002	[.000; .061]	Small effect
	Post-error performance	0.000	.994	.000	[.000; .000]	Small effect
	Total error rate	0.347	.559	.009	[.000; .106]	No effect

Note. Meditation: $N = 22$; PMR: $N = 20$.

Supplementary Material: Table S5

Group means (standard error of means, SEM) of behavioral data (post-error slowing, post-error performance, and error rate) for pre- and post-training, statistics for change scores separated by group (p), group comparisons of change scores (p , η^2) and evaluation of the effect sizes with Cohen (1988). In the evaluation column, the superscript at the effect of change score comparison indicates the group (Meditation, Med, versus Progressive Muscle Relaxation, PMR) that is associated with the stronger effect

		Pre (<i>SEM</i>)	Post (<i>SEM</i>)	Δ_{T2-T1} (<i>SEM</i>)	$p_{\Delta T2-T1}$	p	η^2	Evaluation
Post-error slowing [ms]	Med	19.49 (4.49)	15.82 (4.56)	-3.67 (5.76)	.528	.802	.002	No effect
	PMR			-5.77 (6.05)	.345			
		16.30 (4.71)	10.53 (4.78)					
Post-error performance	Med	0.46 (0.04)	0.60 (0.05)	0.14 (0.03)	.000	.994	.000	No effect
	PMR	0.51 (0.04)	0.65 (0.05)	0.14 (0.03)	.000			
Error rate [%]	Med	34.0 (3.7)	26.4 (3.7)	-0.08 (0.02)	.002	.559	.009	No effect
	PMR			-0.10 (0.02)	.000			
		35.2 (3.8)	25.6 (3.9)					

Note. Meditation: $N = 22$; PMR: $N = 20$.

* $p < .05$, ** $p < .01$, *** $p < .001$; Bonferroni corrected.

Supplementary Material: Table S6

Group means (standard error of means, SEM) of decision criterion c and sensitivity d' for pre- and post-training, statistics for change scores separated by group (p), group comparisons of change scores (p , η^2) and evaluation of the effect sizes with Cohen (1988). In the evaluation column, the superscript at the effect of change score comparison indicates the group (Meditation, Med, versus Progressive Muscle Relaxation, PMR) that is associated with the stronger effect

		Pre (SEM)	Post (SEM)	Δ_{T2-T1} (SEM)	$p_{\Delta T2-T1}$	p	η^2	Evaluation
Decision criterion c	Med	0.41 (0.10)	0.58 (0.10)	0.17 (0.09)	.064	.881	.001	No effect
	PMR	0.45 (0.11)	0.59 (0.11)	0.15 (0.10)	.148			
Sensitivity d'	Med	1.73 (0.21)	2.40 (0.23)	0.67** (0.20)	.002	.184	.047	Small effect ^{Med}
	PMR	1.52 (0.24)	1.78 (0.26)	0.27 (0.23)	.245			

Note. Meditation: $N = 22$; PMR: $N = 17$.

* $p < .05$, ** $p < .01$, *** $p < .001$; Bonferroni corrected.

Supplementary Material: Table S7

Session (pre- vs. post-training) x Group (Meditation versus Progressive Muscle Relaxation, PMR) – General Linear Model of behavioral error data (decision criterion c , sensitivity d'), evaluation of the effect sizes according to Cohen (1988)

Factor	Outcome	$F(37,1)$	p	η^2	90% CI η^2	Evaluation
Session	Decision criterion c	5.614	.023	.132	[.010; .297]	Medium effect
	Sensitivity d'	9.783	.003	.209	[.038; .362]	Large effect
Group	Decision criterion c	0.034	.854	.001	[.000; .036]	No effect
	Sensitivity d'	1.940	.172	.050	[.000; .188]	Small effect
Session x Group	Decision criterion c	0.023	.881	.001	[.000; .025]	No effect
	Sensitivity d'	1.832	.184	.047	[.000; .184]	Small effect

Note. Meditation: $N = 22$; PMR: $N = 17$.

4. Response times and response time standard deviations

Supplementary Material: Table S8

Mean response times (RT), within-subject RT standard deviations (RTSD) (standard error of means; SEM) divided into groups (Meditation versus Progressive Muscle Relaxation, PMR), sessions (pre- and post-training) and Response Type (detected error and detected correct trials)

	error detected		correct detected	
	Pre	Post	Pre	Post
<i>Response times [ms]</i>				
Meditation	383 (15)	342 (19)	463 (17)	423 (20)
PMR	380 (16)	350 (20)	439 (18)	401 (21)
<i>RT standard deviations [ms]</i>				
Meditation	143 (7)	134 (8)	136 (6)	108 (6)
PMR	124 (7)	115 (8)	125 (6)	99 (6)

Note. Meditation: $N = 22$; PMR: $N = 20$.

Supplementary Material: Table S9

Session (pre- vs. post-training) x Group (Meditation versus Progressive Muscle Relaxation, PMR) x Response Type (detected error vs. detected correct) – General Linear Model for response times and response time standard deviations and evaluation of the effect sizes according to Cohen (1988)

Factor	<i>df</i>	<i>F</i>	<i>p</i>	η^2	90% <i>CI</i> η^2	Evaluation
<i>Response Time</i>						
Group	(1, 40)	0.191	.664	.005	[.000; .088]	No effect
Session	(1, 40)	20.937	.000	.344	[.148; .494]	Large effect
Session x Group	(1, 40)	0.159	.692	.004	[.000; .087]	No effect
Response Type	(1, 40)	129.157	.000	.764	[.615; .809]	Large effect
Response Type x Group	(1, 40)	4.287	.045	.097	[.000; .242]	Medium effect
Session x Response Type	(1, 40)	0.136	.714	.003	[.000; .084]	No effect
Session x Response Type x Group	(1, 40)	0.201	.656	.005	[.000; .093]	No effect
<i>Response Time Standard Deviation</i>						
Group	(1, 40)	3.424	.072	.079	[.000; .220]	Medium effect
Session	(1, 40)	33.660	.000	.457	[.232; .567]	Large effect
Session x Group	(1, 40)	0.001	.980	.000	[.000; .001]	No effect
Response Type	(1, 40)	7.301	.010	.154	[.018; .304]	Large effect
Response Type x Group	(1, 40)	1.068	.308	.026	[.000; .144]	Small effect
Session x Response Type	(1, 40)	13.259	.001	.249	[.064; .393]	Large effect
Session x Response Type x Group	(1, 40)	0.107	.746	.003	[.000; .079]	No effect

Note. Meditation: *N* = 22; PMR: *N* = 20.

Results of response times and response time standard deviations. Regarding RTSD, the GLM (Supplementary Material: Table S9) revealed a significant effect of Response Type [$F(1, 40) = 7.301, p < .05, \eta^2 = .154$]. Participants' responses showed higher RTSD in detected erroneous trials (129 ± 5 ms) compared to correct trials (117 ± 4 ms). A significant effect of Session [$F(1, 40) = 33.660, p < .001, \eta^2 = .457$] showed that response time in Session 2 (114 ± 4 ms) was less variable than in Session 1 (132 ± 4 ms). A significant interaction Session x Response Type effect [$F(1, 40) = 13.259, p < .01, \eta^2 = .249$] revealed that in Session 1, response time in detected erroneous trials (134 ± 5 ms) and correct trials (130 ± 4 ms) did not differ significantly ($p = .481$). In Session 2, for detected erroneous trials (125 ± 6 ms), response times were more varied compared to correct trials (104 ± 4 ms, $p < .001$). Regarding detected errors, participants' response time differed in variability between both sessions but only marginally significantly (134 ± 5 ms vs. 125 ± 6 ms, $p = .054$). Participants also responded with smaller RTSD in Session 2 when making correct responses (130 ± 4 ms vs. 104 ± 4 ms, $p < .001$). Furthermore, the main effect of Group was marginally significant for RTSD with a medium effect ($\eta^2 = .079$), with slightly higher RTSD in Meditation than in PMR. The small, yet non-significant effect of Response Type by Group interaction for RTSD ($\eta^2 = .026$) showed that, while participants in the Meditation group had significantly higher RTSD for errors than for correct responses ($p < .01$), this was not the case for PMR ($p = .256$).

Discussion. The Meditation group showed lower response time variability for correct trials than for errors, which was not the case for PMR. Especially for correct trials, response time in Session 2 was less various than in Session 1. Reduction of response time variability for correct trials was related to an improvement in emotional acceptance and stress reduction, yet not significantly.

5. Correlations of changes in Pe, RT and RTSD differences and self-report rating

Hypotheses. To understand the underlying mechanisms of possible changes in Pe and to control separately for moderating effects of the subcomponents emotional acceptance and awareness on training effects on Pe amplitude and other objective outcomes, and in case of significant changes in psychometric, behavioral, and/or neurophysiological scores, Pearson's correlations of these change scores were calculated.

Methods. Since there were significant changes for several behavioral data (decision criterion; sensitivity; error rate; post-error performance; response time for correct trials and for detected errors; RTSD for correct trials and for the area around peak amplitudes of Pe for detected errors), we calculated the differences (T2 minus T1) and correlated these values with the significant changes in self-report outcomes (mindfulness measured with FFA, acceptance factor of PHLMS, ASS-SYM, Supplementary Material: Table S10).

Supplementary Material: Table S10

Correlations (r and p -values) of significant change scores ($\Delta T2-T1$ for mindfulness, $\Delta T1-T2$ for symptoms) of self-report ratings, with significant changes in Pe- area around peak amplitude (mean amplitude for detected errors) and behavioral changes (decision criterion; sensitivity; error rate; post-error performance, PEP; response time, RT - for correct trials and detected errors; response time standard deviations, RTSD for correct trials)

Change scores ($\Delta T2-T1$)	$\Delta T2-T1$ Mindfulness (FFA)		$\Delta T2-T1$ PHLMS Awareness		$\Delta T2-T1$ PHLMS Acceptance		$\Delta T1-T2$ ASS-SYM	
	r	p	r	p	r	p	r	p
Pe area (Cz) detected errors ($N = 42$)	-.140	.377	.117	.462	.233	.138	-.038	.809
Decision criterion ($N = 39$)	.109	.509	.199	.224	.163	.322	.289	.074
Sensitivity ($N = 39$)	.083	.614	.147	.372	.214	.191	.060	.717
Error rate ($N = 42$)	-.269	.085	-.159	.314	-.235	.134	-.156	.325
PEP ($N = 42$)	-.049	.760	-.037	.814	.074	.640	.052	.746
RT correct ($N = 42$)	.273	.080	.103	.516	.261	.095	.149	.348
RT detected errors ($N = 42$)	-.069	.665	-.011	.943	.024	.881	-.015	.926
RTSD correct ($N = 42$)	-.209	.184	-.162	.305	-.289	.064	-.349*	.024

Note.

FFA = Freiburger Fragebogen zur Achtsamkeit

PHLMS = Philadelphia Mindfulness Scale

ASS-SYM = Änderungssensitive Symptomliste zu Entspannungserleben, Wohlbefinden, Beschwerden- und Problembelastungen

Results. The only significant correlation indicated a relation between a decrease in stress symptoms (ASS-SYM) and a decrease of RTSD for correct trials ($r = -.349$, $p = .024$). Marginally significant ($r = .289$, $p = .074$) was a correlation between an increase in decision criterion with a decrease in stress symptoms (ASS-SYM). The relationship of an increase of mindfulness (FFA) with a decrease of total error rate could not reach the 5%-level of

significance ($r = -.269, p = .085$). A change in mindfulness (FFA) correlated marginally significantly with change in RT for correct trials ($r = .273, p = .080$). Hence, an increase in mindfulness was related with a smaller decrease in correct RT. An increase of acceptance (PHLMS) was also marginally significantly related to a smaller RT decrease for correct trials ($r = .261, p = .095$). A decrease of RTSD for correct trials correlated non-significantly with an increase in acceptance (PHLMS) ($r = -.289, p = .064$). Changes in Pe did not correlate with any of the self-report ratings (all $p > .10$).

Discussion. Using a mindfulness scale that differentiates between the factors of awareness and emotional acceptance was intended to reveal insights regarding the underlying mechanisms of a mindfulness intervention and to control separately for moderating effects of these subcomponents.

6. Sub-sample analyses with undetected errors

For the sake of completeness, we performed a second set of analyses for the sub-sample, which performed enough undetected errors [univariate repeated-measures general linear model (GLM) for each dependent variable (RT, within-subject RT standard deviation, Ne/ERN amplitude, Pe amplitude), within-subject factor for Session (first vs. second) and Response Type (correct response, detected error and undetected error) with factor Group (PMR vs. Meditation) followed by Bonferroni post-hoc comparisons with alpha-adjusted p values. In case sphericity assumption was violated, Greenhouse-Geisser corrected degrees of freedom were used]. Outlier analysis for all cases with enough undetected errors showed two extreme values for area around peak in FCz for Ne/ERN of undetected errors. These two outliers had to be excluded for the comparison of undetected and detected errors..

6.1 ERPs

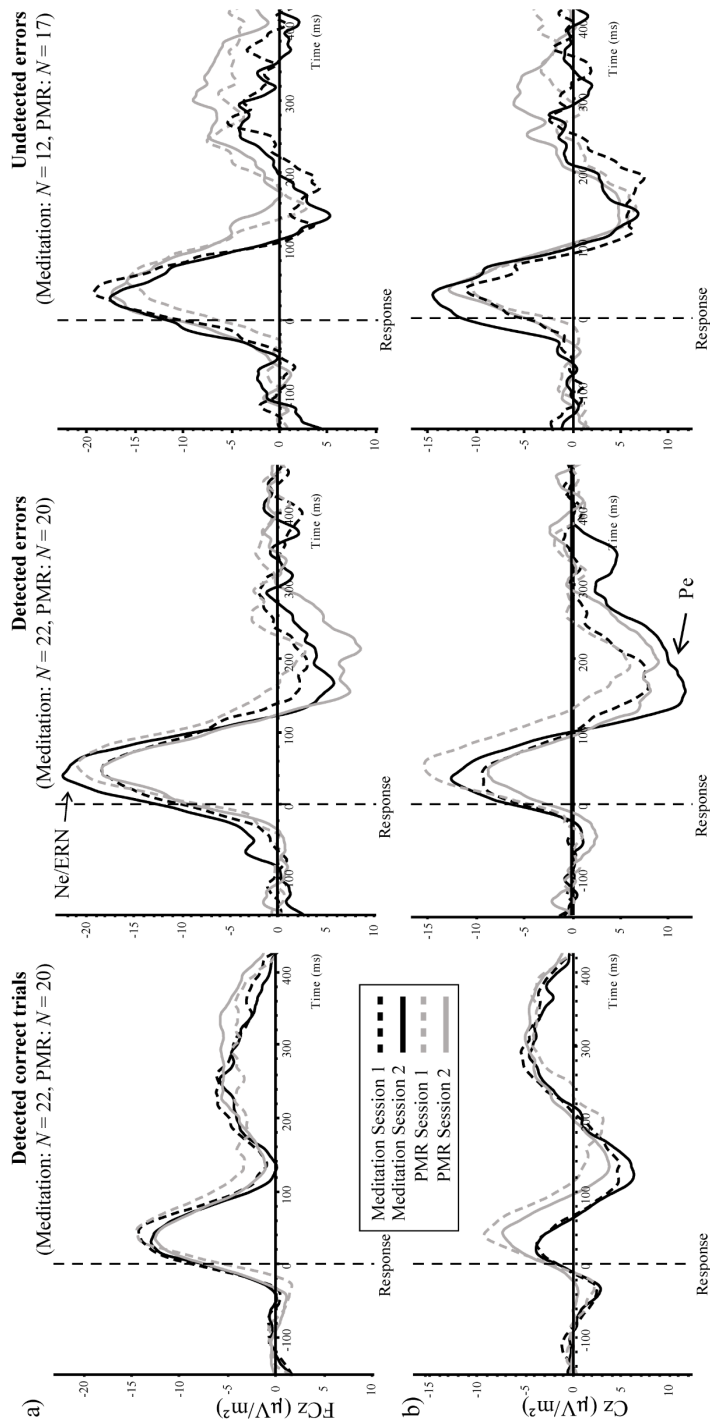
The mean ERP area around peak amplitudes for Ne/ERN and Pe are presented in Table S10; the grand average response-locked ERP waveforms at FCz and Cz are presented in Figure S2 a and b, respectively.

Supplementary Material: Table S11

Mean area around peak (Ne/ERN peak; Pe peak) amplitudes (standard error of means; SEM) divided into groups (Meditation versus Progressive Muscle Relaxation, PMR), sessions (pre- and post-training) and Response Type (detected and undetected error, and detected correct trials)

	error detected		error undetected		correct detected	
	Pre	Post	Pre	Post	Pre	Post
Ne/ERN Peak [$\mu\text{V}/\text{m}^2$]						
Meditation	-8.79 (2.38)	-11.18 (2.39)	-7.22 (1.86)	-8.17 (2.41)	-6.49 (2.19)	-6.62 (2.13)
PMR	-9.38 (2.00)	-8.04 (2.01)	-7.24 (1.56)	-10.03 (2.03)	-8.51 (1.84)	-7.41 (1.79)
Pe Peak [$\mu\text{V}/\text{m}^2$]						
Meditation	4.85 (2.95)	5.57 (3.42)	3.69 (3.17)	0.03 (2.32)	2.45 (2.52)	4.83 (2.14)
PMR	0.99 (2.48)	6.17 (2.87)	1.67 (2.66)	0.68 (1.95)	0.00 (2.12)	1.04 (1.80)

Note. Meditation: $N = 12$; PMR: $N = 17$.



Supplementary Material: Figure S2

Figure S2. Current source density response-locked event related potentials ($\mu\text{V}/\text{m}^2$) at a) FCz and b) Cz for detected and undetected errors and detected correct trials divided for groups and sessions. Response onset is at 0 ms. Negative is plotted up

6.2 Ne/ERN with undetected errors

A three-way GLM for Ne/ERN (or CRN for correct trials) area around peak amplitudes was performed (Table S11) and revealed no significant effects. A medium effect for Response Type [$F(2, 54) = 2.19, p = .122, \eta^2 = .075$] suggested a slightly more negative amplitude for detected errors ($-9.35 \pm 1.23 \mu\text{V}/\text{m}^2$) compared to correct trials ($-7.26 \pm 1.26 \mu\text{V}/\text{m}^2, p = .151$). The detected and undetected erroneous trials ($-8.16 \pm 1.10 \mu\text{V}/\text{m}^2$) did not differ in amplitude ($p = .870$). Small effects for Session ($\eta^2 = .010$), for Response Type-by-Group interaction ($\eta^2 = .036$), for Session-by-Response Type interaction ($\eta^2 = .025$) and Session-by-Response Type-by-Group interaction ($\eta^2 = .035$) were observed (for details see Table S11).

6.3 Pe with undetected errors

A three-way GLM for Pe area around peak amplitudes was calculated (Table S11) and it revealed a significant effect for Response Type [$F(2, 54) = 4.33, p < .05, \eta^2 = .138$]; there was a more positive amplitude for detected ($4.39 \pm 1.91 \mu\text{V}/\text{m}^2$) compared to undetected erroneous trials ($1.52 \pm 1.55 \mu\text{V}/\text{m}^2, p < .05$) but not compared to correct trials ($2.08 \pm 1.39 \mu\text{V}/\text{m}^2, p = .166$). Undetected errors and correct trials did not differ in amplitude ($p = 1.00$).

There was also a marginally significant medium effect of Session-by-Response Type [$F(1.57, 42.34) = 3.26, p = .060, \eta^2 = .108$]. While the Response Type did not differ in Session 1 (detected errors: $2.92 \pm 1.93 \mu\text{V}/\text{m}^2$, undetected errors: $2.68 \pm 2.07 \mu\text{V}/\text{m}^2$, correct trials: $1.22 \pm 1.65 \mu\text{V}/\text{m}^2$, all $p > .10$), in Session 2, detected errors ($5.87 \pm 2.23 \mu\text{V}/\text{m}^2$) resulted in larger Pe than undetected errors ($0.36 \pm 1.51 \mu\text{V}/\text{m}^2, p = .016$) but not compared to correct trials ($2.94 \pm 1.40 \mu\text{V}/\text{m}^2, p = .359$). Undetected errors and correct trials did not differ ($p = .192$). Only detected errors changed marginally significant from Session 1 to Session 2 ($2.92 \pm 1.93 \mu\text{V}/\text{m}^2$ versus $5.87 \pm 2.23 \mu\text{V}/\text{m}^2, p = .088$), while the other Response Types did not change significantly (all $p < .10$).

No other effect was significant (for all $p > .10$). Small effects of Group ($\eta^2 = .013$), Session ($\eta^2 = .020$), as well as Session-by-Group interaction ($\eta^2 = .031$), Response Type-by-Group interaction ($\eta^2 = .025$), and Session-by-Response Type-by-Group interaction ($\eta^2 = .034$) were observed (for details see Table S11).

Supplementary Material: Table S12

Session (pre- vs. post-training) x Group (Meditation versus Progressive Muscle Relaxation, PMR) x Response Type (detected error vs. undetected error vs. detected correct) – General Linear Model for Ne/ERN- and Pe-area around peak amplitudes and evaluation of the effect sizes according to Cohen (1988)

Factor	<i>df</i>	<i>F</i>	<i>p</i>	η^2	90% <i>CI</i> η^2	Evaluation
<i>Ne/ERN</i>						
Group	(1, 27)	0.03	.866	.001	[.000; .043]	No effect
Session	(1, 27)	0.28	.598	.010	[.000; .136]	Small effect
Session x Group	(1, 27)	0.19	.667	.007	[.000; .123]	No effect
Response Type	(2, 54)	2.19	.122	.075	[.000; .183]	Medium effect
Response Type x Group	(2, 54)	1.02	.367	.036	[.000; .123]	Small effect
Session x Response Type	(1.49, 40.34) ^a	0.69	.465	.025	[.000; .127]	Small effect
Session x Response Type x Group	(1.49, 40.34) ^a	0.97	.366	.035	[.000; .147]	Small effect
<i>Pe</i>						
Group	(1, 27)	0.36	.555	.013	[.000; .145]	Small effect
Session	(1, 27)	0.56	.462	.020	[.000; .164]	Small effect
Session x Group	(1, 27)	0.85	.364	.031	[.000; .185]	Small effect
Response Type	(2, 54)	4.33	.018	.138	[.014; .262]	Large effect
Response Type x Group	(2, 54)	0.70	.499	.025	[.000; .101]	Small effect
Session x Response Type	(1.57, 42.34) ^a	3.26	.060	.108	[.000; .248]	Medium effect
Session x Response Type x Group	(1.57, 42.34) ^a	0.94	.377	.034	[.000; .140]	Small effect

^a Greenhouse-Geisser corrected degrees of freedom were used due to a violation of sphericity. Note. Meditation: *N* = 12; PMR: *N* = 17.

6.4 Response time with undetected errors

In Table S12, RT data are presented separately for Response Type (detected errors, undetected errors, correct trials), for Session and Group.

Supplementary Material: Table S13

Mean response times (RT), within-subject RT standard deviations (RTSD) (standard error of means; SEM) divided into groups (Meditation versus Progressive Muscle Relaxation, PMR), sessions (pre- and post-training) and Response Type (detected and undetected error, and detected correct trials)

	error detected		error undetected		correct detected	
	Pre	Post	Pre	Post	Pre	Post
Response times [ms]						
Meditation	384 (20)	357 (22)	440 (26)	441 (31)	465 (25)	441 (23)
PMR	383 (17)	355 (18)	414 (22)	411 (26)	443 (21)	410 (20)
RT standard deviations [ms]						
Meditation	141 (9)	138 (12)	166 (9)	148 (11)	134 (6)	103 (6)
PMR	127 (8)	121 (10)	142 (8)	130 (9)	129 (5)	103 (5)

Note: Meditation: $N = 12$; PMR: $N = 17$.

The Response Type x Session x Group GLM (Table S13) revealed a significant effect of Response Type on RT [$F(1.44, 38.99) = 33.876, p < .001, \eta^2 = .556$]. Participants responded faster in detected erroneous trials (mean and standard error of mean: 370 ± 13 ms) than in undetected erroneous trials (427 ± 17 ms, $p < .001$) and correct trials (440 ± 15 ms, $p < .001$), whereas undetected erroneous trials and correct trials did not differ ($p = .376$).

A significant effect of Session [$F(1, 27) = 4.540, p < .05, \eta^2 = .144$] revealed faster responding after the intervention (402 ± 16 ms) compared to before (422 ± 14 ms).

There was also a marginally significant interaction of Session and Response Type with a medium effect [$F(2, 54) = 2.937, p = .062, \eta^2 = .098$]. In Session 1, responses in detected

erroneous trials (384 ± 14 ms) were the fastest ($p < .01$ and $p < .001$), followed by responses in undetected erroneous (427 ± 17 ms) that were faster ($p < .05$) than responses in correct trials (454 ± 16 ms). In Session 2, responses in detected erroneous trials (356 ± 14 ms) were made faster than responses in both undetected erroneous (426 ± 20 ms, $p < .001$) and correct trials (425 ± 15 ms, $p < .001$), which did not differ ($p = 1.00$). Participants responded slower in Session 1 compared to Session 2 when making detected errors (384 ± 14 ms vs. 356 ± 14 ms, $p < .05$) or correct trials (454 ± 16 ms vs. 425 ± 15 ms, $p < .05$), not when making undetected errors (427 ± 17 ms vs. 426 ± 20 ms, $p = .913$). A small effect of the Group ($\eta^2 = .016$) and for the Response Type-by-Group interaction ($\eta^2 = .047$) were observed (for details see Table S13), Meditation showing generally slightly slower responses.

Supplementary Material: Table S14

Session (pre- vs. post-training) x Group (Meditation versus Progressive Muscle Relaxation, PMR) x Response Type (detected error vs. undetected error vs. detected correct) – General Linear Model for response times and response time standard deviations and evaluation of the effect sizes according to Cohen (1988)

Factor	<i>df</i>	<i>F</i>	<i>p</i>	η^2	90% <i>CI</i> η^2	Evaluation
<i>Response Time</i>						
Group	(1, 27)	.427	.519	.016	[-.000; .152]	Small effect
Session	(1, 27)	4.540	.042	.144	[-.003; .335]	Medium effect
Session x Group	(1, 27)	.071	.792	.003	[-.000; .092]	No effect
Response Type	(1.44, 38.99) ^a	33.876	.001	.556	[-.359; .663]	Large effect
Response Type x Group	(1.44, 38.99) ^a	1.327	.270	.047	[-.000; .171]	Small effect
Session x Response Type	(2, 54)	2.937	.062	.098	[-.000; .214]	Medium effect
Session x Response Type x Group	(2, 54)	.045	.956	.002	[-.000; .027]	No effect
<i>Response Time Standard Deviation</i>						
Group	(1, 27)	2.317	.140	.079	[-.000; .260]	Medium effect
Session	(1, 27)	16.106	.001	.374	[-.133; .542]	Large effect
Session x Group	(1, 27)	.105	.748	.004	[-.000; .104]	No effect
Response Type	(2, 54)	14.142	.001	.344	[-.162; .467]	Large effect
Response Type x Group	(2, 54)	1.493	.234	.052	[-.000; .150]	Small effect
Session x Response Type	(1.43, 38.59) ^a	5.040	.020	.157	[-.015; .313]	Large effect
Session x Response Type x Group	(1.43, 38.59) ^a	.195	.749	.007	[-.000; .079]	No effect

^a Greenhouse-Geisser corrected degrees of freedom were used due to a violation of sphericity.
Note. Meditation: *N* = 12; PMR: *N* = 17.

6.5 Response time variability with undetected errors

The GLM (Table S13) revealed a significant effect of Response Type on RTSD [$F(2, 54) = 14.142, p < .001, \eta^2 = .344$]. Participants' responses showed the highest RTSD in undetected erroneous trials (147 ± 5 ms) compared to detected erroneous trials (132 ± 6 ms, $p < .05$) that both showed higher RTSD than in correct trials (117 ± 4 ms, $p < .001$ and $p < .05$). There was also an effect of Session [$F(1, 31) = 16.106, p < .001, \eta^2 = .374$]: response time in Session 2 (124 ± 5 ms) was less various than in Session 1 (140 ± 4 ms). Finally, there was a significant interaction Session x Response Type effect [$F(1.43, 38.59) = 5.040, p < .05, \eta^2 = .157$]. In Session 1, response time in undetected erroneous trials (154 ± 6 ms) was more various than response time in both detected erroneous trials (134 ± 6 ms, $p < .05$) and correct trials (132 ± 4 ms, $p < .01$) that not differed significantly ($p = 1.00$). In Session 2, detected erroneous trials (130 ± 8 ms) did not differ from undetected erroneous trials (139 ± 7 ms, $p = .745$), but both response times were more various compared to correct trials (103 ± 4 ms, $p < .01$ and $p < .001$, respectively). Regarding detected errors, participants' response time did not differ in variability between both sessions (134 ± 6 ms vs. 130 ± 8 ms, $p = .414$). The same was the case for undetected errors (154 ± 6 ms vs. 139 ± 7 ms, $p = .060$). Nevertheless, participants responded less various in response time in Session 2 when making correct responses (132 ± 4 ms vs. 103 ± 4 ms, $p < .001$). Medium, but not significant effect of Group ($\eta^2 = .079$) as well as a small effect of Response Type-by-Group interaction ($\eta^2 = .052$) were observed (for details see Table S13).