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ORIGINAL PAPER

Mindful Text Comprehension: Meditation Training Improves Reading Comprehension of Meditation Novices

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Abstract

Objectives Research on the effects of meditation practice on reading performance is a new and promising field of research. However, the evidence on whether meditation improves reading comprehension and/or speed in continuous reading is inconclusive. The present work addresses this question.

Method For the present longitudinal study, undergraduate students ($n = 52$) participated in a 6-week mindfulness meditation course or an active control condition. We assessed reading comprehension and speed before and after the intervention/control condition, as well as emotion regulation, sustained attention, and personality traits.

Results Reading comprehension improved significantly after the meditation intervention ($B = 2.15$, $t = 3.47$, $p = 0.002$, $d = 0.69$), but reading speed did not change, contrary to our expectations. The control group showed no significant changes in either text comprehension or reading speed. Further, we found that meditation led to better attention capacity. Improved attention was positively associated with improved reading comprehension in the meditation group, though attention capacity did not mediate the effect on text comprehension. While we found that meditation can increase the acceptance of one's own emotions and decrease emotional overload, these covariates did not affect comprehension performance.

Conclusions The present work shows that mindfulness meditation improves attention capacity and text comprehension. However, mindfulness meditation does not affect reading speed. Finally, we confirmed that meditation can help in emotion regulation.

Preregistration This study is not preregistered.

Keywords Meditation · Reading comprehension · Attention · Text comprehension · Reading speed · Mindfulness

Reading comprehension is an important field of research, given that reading for meaning is a key basis for successful participation in our society. Successful reading can be broken down into two main components: Word decoding and language comprehension (Gough & Tunmer, 1986; see Lonigan et al., 2018, for a recent review). In this context, successful word decoding is defined as efficient letter and word recognition, often assessed in relatively pure form by the ability to read out loud pseudowords (letter-strings without meaning). Language comprehension refers to "the ability to take lexical information … and derive sentence and discourse interpretations" (Hoover & Gough, 1990, p. 131). Over the last decades, research has made great progress in identifying important processes and mechanisms for successful reading comprehension (Perfetti et al., 2005). To list a few examples, vocabulary breadth and depth (Cain & Oakhill, 2014), reasoning skills (Cutting & Scarborough, 2006), and comprehension monitoring (Vorstius et al., 2013) have been shown to constitute essential components for the ability to understand texts adequately.

Despite significant societal investment and growing knowledge of effective teaching, there are still a substantial number of students, in different forms of schooling, who lack essential reading comprehension skills. For example, in Germany, about 20% of the 15-year-olds were not able to grasp the meaning of texts and to reflect on it (PISA, 2019). Therefore, unconventional approaches to solving the problem should also be considered. Meditation is a practice that is at least more than 2500 years old (Pandurangi et al.,

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2017) and intends to calm the mind, the emotions, and the thoughts. During meditation, practitioner learns to let a thought or an emotion come and go without judging it as good or bad. Emotion or thought is noted, but meditator is not getting further involved with it or lets mind get carried away because of that thought or emotion (Kabat-Zinn, 1990). A mind trained in this way is stable; it is not easily upset or distracted. This means that such a mind has the ideal prerequisites for mastering tasks where it is important to remain focused for a longer period. We follow the definition of mindfulness as full attention to the experiences of every present moment and the complete non-judgmental acceptance of all these experiences (Kabat-Zinn, 1990).

Research on the effects of meditation showed that meditation can improve attentional control (MacLean et al., 2010; see Lutz et al., 2008 for a review) and emotion regulation (Shapiro et al., 2008; Zhang et al., 2019), and reduce mind wandering (Mrazek et al., 2012; Taraban et al., 2017). All of these skills might be very helpful to stay on task during reading-related assessments like reading comprehension and speed. Following this rationale, in recent years, a new and promising field of research has started to explore the effects of meditation practice on performance in reading. Tarrasch et al. (2016) reported that dyslectic individuals and/or individuals with attention deficits demonstrated 19% fewer reading errors after a 2-month course in mindfulness meditation. At the same time, sustained attention also improved in these participants. Further, extensive meditation practice was found to reduce mindless reading and mind wandering during reading (Zanesco et al., 2016). A recent pilot study by Rice et al. (2020) suggested that as little as 5 days of mindfulness meditation practice can increase reading speed. Lusnig et al. (2020, 2022) found that various meditation technics can accelerate single word processing, while the capacity for emotion regulation was demonstrated by attenuated valence ratings for emotional words.

There is little research on whether meditation also has a positive effect on reading comprehension, and the results have been inconclusive. In a study by Clinton et al. (2018), 105 undergraduate students appeared to demonstrate better reading comprehension compared to a control group after practicing mindful breathing for as little as 15 min. However, comprehension was assessed using the Nelson-Denny test, which has been criticized for lack of validity, as many items can be solved correctly without reading the test passages (e.g., Coleman et al., 2010).

In a study by Mrazek et al. (2013), 48 undergraduate students participated either in a mindfulness meditation course or in a nutrition course. During the 2-week period, each course was held eight times for 45 min each. Before and after the intervention/control condition, participants completed assignments on reading comprehension and working memory. In addition, mind wandering during both tasks was assessed. After 2 weeks of meditation training, participants demonstrated both improved reading comprehension and working memory performance. Mind wandering during the assessments was reduced. The active control condition did not lead to any significant changes in reading comprehension, working memory performance, or mind wandering.

Some studies did not show effects of meditation on reading performance. Linden (1973) found that 26 third-grade students became more field-independent and less test anxious after 18 weeks of meditation practice. However, the meditation practice did not affect students' reading achievement, which included measures of reading comprehension. In a recent pilot study, Benney et al. (2021) examined whether mindfulness training, combined with reading fluency training, would help a fourth-grade student with learning disabilities to improve his reading fluency compared to the reading fluency training without a mindfulness intervention. Various analyses of these data did not find conclusive evidence on whether meditation leads to improved reading fluency.

The present study addressed these conflicting findings and aimed to answer the question of whether mindfulness meditation can affect reading comprehension. In addition, the effects of mindfulness meditation on reading speed were examined. Concentration capacity, emotion regulation, and Big Five personality traits were assessed as covariates. A mindfulness group (MG) practiced mindfulness meditation for 2 hr per week over 6 weeks. The control group (CG) studied for university classes during the same periods. Before and after the intervention/control condition, participants completed a standardized assessment of reading comprehension and reading speed, along with tests of concentration ability and emotion regulation. We hypothesized that mindfulness meditation would lead to better reading comprehension and that the active control condition would not change reading performance. Further hypotheses were that individuals' reading speed would improve after the 6-week course in mindfulness meditation. We expected that participants in the MG would increase their attention skills and improve emotion regulation. For the CG, no significant changes in attentional performance and emotion regulation were expected.

Method

Participants

Undergraduate students from the University of Wuppertal took part in the present study. All of them were German native speakers. Half of them participated in the MG (total 26, 23 female, 3 male, 18–32 years of age, $M_{age} = 20.92$, $SD_{age} = 3.41$), and the other half in the CG (total 26,

22 female, 4 male, 19–35 years of age, $M_{age} = 20.34$, $SD_{age} = 3.45$). Groups did not differ significantly in both age $t(25) = 0.59$, $p = 0.28$ and gender $t(25) = -0.4$, $p = 0.35$. To ensure random assignment to the two groups, participants were told that the mindfulness course and the study group (active control condition) would take place in two different time slots in the morning of the same day. They were asked to sign up for one time slot without knowing at which time the mindfulness intervention and at which time the active control condition would take place. Our sample size of $n = 52$ is comparable to Mrazek et al. (2013), who found effects of meditation on reading comprehension in a study with 48 participants. Inclusion criteria comprised no previous meditation experience, no history of psychiatric disorders, and no reading and writing difficulties.

Procedure

For the pre-test, all participants first completed the reading speed and comprehension test, then the attention test, the emotion experience test, the vocabulary intelligence test, and the Big Five personality test. Starting the following week, participants, who had signed up for Time Slot A participated in a 6-week mindfulness course, participants, who had signed up for Time Slot B participated a 6-week study group. One to 5 days after the end of the intervention/control condition, all individuals participated in the post-test, completing the reading speed and comprehension test in a parallel form, the attention test, the emotion experience test, and the Big Five personality test.

For 6 consecutive weeks, both the mindfulness intervention and the control active condition were held in the morning on the same day of the week. An experienced meditation trainer led the meditation group. For the CG, an undergraduate assistant monitored that the participants worked silently for a university class. Each mindfulness meditation session lasted 2 hr and consisted of a 15-min welcome and setting up the necessary materials together (mats, sitting aids…), followed by a 30-min explanation of the meditation technique to be practiced in that session, discussion, and answering questions. Then participants for 25 min followed a guided sitting meditation, a 15-min guided walking meditation, and again a 25-min guided sitting meditation. The last 15 min was used for answering any remaining questions and cleaning up the aids. Table 1 contains information about the course content of each session. The active control condition was designed to involve participants in a silent and mentally active way that resembled their usual day-to-day activities. The participants of the present study were all undergraduate students; therefore, we selected a silent study group as an adequate active control condition. Participants were recruited via online advertisements. For their participation, individuals received course credits. All participants signed a written informed consent form prior to their participation in the study.

Measures

Attention Test

An attention test ("d2-Revision test") was used to assess the ability to focus on task and the participant's sustained attention. Under time pressure, the letter "d" with two marks is to be found among similar-looking distractor letters. The test contains 57 items. The two scales "number of processed target objects" and "concentration capacity" demonstrated Cronbach's alpha values between $\alpha = 0.89$ and 0.95, and the scale "percentage of errors" values between $\alpha = 0.80$ and 0.91. Empirical evidence for criterion and construct validity was reported by the authors (Brickenkamp et al., 2010).

To assess the internal consistency of the data of the present study, McDonald's omega (ω) and Cronbach's alpha (α) were calculated for the used test scales. All following interpretations of the internal consistency of the data of the present study are based on McDonald's omega values. All scales of the attention test demonstrated very good internal consistency ("concentration capacity" $\omega = 0.96$, $\alpha = 0.92$; "percentage of errors" $\omega = 0.93$, $\alpha = 0.86$; "number of processed target objects" $\omega = 0.97$, $\alpha = 0.96$).

Table 1 Mindfulness class protocol

Week	Course contents
1	Introduction to suitable sitting postures for meditation, the body scan (relaxation method of the body), and walking meditation.
2	Introduction of various techniques to achieve continuous concentration on the breath.
3	Mindful awareness of the breath, physical sensations, emotions, and thoughts. Calming the mind.
4	Being in the present moment without being carried away by physical sensations, emotions, and thoughts. Staying in silence.
5	Learning not to evaluate the encounters of the present moment as good or bad or identify with them, but to see them in a neutral way and let them go.
6	Consolidation of the techniques learned.

Emotion Experience Test

The emotion experience test ("Skalen zum Erleben von Emotionen") that we used consists of 42 items and the 7 scales: "acceptance of one's own emotions", "experiencing emotion overload", "experiencing lack of emotions", "body-related symbolization of emotions", "imaginative symbolization of emotions", "experience of emotion regulation", and "experience of self-control". The assessment is intended to reflect how people evaluate, perceive, and deal with their feelings. The scales demonstrated an internal consistency between 0.70 and 0.86 (Cronbach's alpha). Retest reliability was in a range of 0.60 to 0.90 across measurement time points of 2, 3, 4, 10, and 14 weeks for all scales (Behr & Becker, 2004).

In the present study, six of the seven scales of the emotion experience test showed good internal consistency ("acceptance of one's own emotions" $\omega = 0.88$, $\alpha = 0.83$; "experiencing emotion overload" $\omega = 0.90$, $\alpha = 0.85$; "body-related symbolization of emotions" $\omega = 0.87$, $\alpha = 0.81$; "imaginative symbolization of emotions" $\omega = 0.87$, $\alpha = 0.79$; "experiencing lack of emotions" $\omega = 0.84$, $\alpha = 0.79$; "experience of self-control" $\omega = 0.89$, $\alpha = 0.84$). An item example for "acceptance of one's own emotions" is "I stand by my sentiments". One scale showed acceptable internal consistency ("experience of emotion regulation" $\omega = 0.71$, $\alpha = 0.64$). An item example for the scale "experience of emotion regulation" is "When I get nervous, I usually know how to calm myself down".

Big Five Personality Test

The Big Five personality test measures personality traits as captured in the Big Five model of personality with 72 items. In addition to the original five scales, "Neuroticism" (Cronbach's alpha, $\alpha = 0.90$), "Conscientiousness" ($\alpha = 0.77$), "Extraversion" ($\alpha = 0.87$), "Agreeableness" ($\alpha = 0.76$), and "Openness to Experience" ($\alpha = 0.76$), the revised version added three scales, "Need for Power and Influence" ($\alpha = 0.78$), "Need for Security and Peace" ($\alpha = 0.84$), and "Need for Achievement and Performance" ($\alpha = 0.82$). The test showed good factorial validity (Satow, 2011).

In the present study, 5 of the 8 Big Five scales showed good internal consistency ("Neuroticism" $\omega = 0.90$, $\alpha = 0.86$; "Extraversion" $\omega = 0.92$, $\alpha = 0.88$; "Need for Power and Influence" $\omega = 0.85$, $\alpha = 0.73$; "Need for Security and Peace" $\omega = 0.91$, $\alpha = 0.85$; "Need for Achievement and Performance" $\omega = 0.86$, $\alpha = 0.76$). An example for an item for the scale "Neuroticism" is "I am often sad for no reason". Three Big Five scales showed acceptable internal consistency ("Conscientiousness" $\omega = 0.79$, $\alpha = 0.70$; "Agreeableness" $\omega = 0.77$, $\alpha = 0.68$; "Openness to Experience" $\omega = 0.71$, $\alpha = 0.58$). An item example for "Conscientiousness" is "I have my principles and stick to them".

Reading Speed and Comprehension Test

To assess reading comprehension and reading speed, participants completed randomly assigned parallel versions of a German reading speed and comprehension test ("Lesegeschwindigkeits- und Verständnistest") at the beginning of the study (Schneider et al., 2017). For this assessment, participants have to read a text as far as they can within 6 min. Reading speed is measured by the number of words read. While participants read the text, they also have to complete a cloze test to evaluate their reading comprehension. Every 4–7 lines, there is a square bracket in the text that contains three words. The participants have to decide which of these words fit the context of the text; they can edit a maximum of 47 items. Concerning correct, incorrect, and omitted answers, the value of text comprehension is formed using a point system. The used reading speed and comprehension test is widely accepted in German-speaking countries and provided good retest reliabilities, with *r*-values ranging between 0.72 and 0.89. Correlative analyses with external criteria (e.g., with the reading comprehension test from PISA 2000) provided evidence for convergent and discriminant validity (Schneider et al., 2017).

For the reading speed and comprehension test, it is not useful to assess internal consistency. "Due to the conception of the [reading speed and reading comprehension] test […], the reliability of the LGVT 6–12 is determined via the retest reliability, since the otherwise usual measures such as the split-half coefficient due to Spearman-Brown, [or] Cronbach's Alpha […] cannot be meaningfully calculated, since the differentiation between the students is […] made via […] the number of items solved" (Schneider et al., 2017, p. 17; English translation). Therefore, we did not include Cronbach's alpha or McDonald's omega values for the reading speed and reading comprehension test.

Vocabulary Intelligence Test

In the 37 items of the multiple-choice vocabulary intelligence test, a German word is to be found among four similar pseudoword distractors. Published retest reliability included correlations of $r = 0.95$ after 6 months and $r = 0.87$ after 14 months. Empirical evidence for good criterion validity was published (Lehrl, 2005). Because of the design of the test, reliability is determined by retest reliability. As for the reading comprehension test, the differentiation between the participants is made via the number solved items; therefore, a meaningful calculation of Cronbach's alpha/McDonald's omega is not possible.

Data Analyses

All assessments were analyzed using linear mixed-effects models (LMEs). The calculations were executed with the statistical software environment R (version 4.0.5, http://cran.r-project.org). The library lme4 was used with the lmer function (version 1.1–14, Bates et al., 2015), which fits an LME to the data. "Groups" (MG/CG) and "time" (before/after intervention/control condition) were fitted as fixed effects, as a random effect, we fitted "participants"; in this way, it became possible to handle participant variance more sensitively. The assumption of normality of the residuals was verified by qqplots. Approximately 1% of the data was not used in the calculations because these data points were not in the range of − 3 and 3 standard deviations of the residual error. When we found significant interactions of "group" and "time", subsequently separate LMEs for each of the two groups were calculated in order to examine in which group the "time" effect had occurred. For the subsequent analyses, Bonferroni corrections were applied. The Bonferroni adjusted alpha level was 0.025 since there were two tests conducted in the subsequent analyses (0.05/2). Only results that survived Bonferroni corrections are reported. We provide estimates of regression coefficients, their standard errors, and *t*-values. On the basis of the Satterthwaite approximation, we provide *p*-values (lmerTest package, version 2.0–36, Kuznetsova et al., 2017). The mediation model was conducted using the lavaan library (version 0.6–11, Rosseel, 2012). McDonald's omega (ω) was calculated using the psych package (version 2.2.5, Revelle, 2022).

Results

The results of the vocabulary intelligence test revealed that participants in both groups did not differ significantly in baseline verbal intelligence ($t(25) = 1.62$, $p = 0.11$), MG ($M = 25.83$, $SD = 3.35$), and CG ($M = 24.36$, $SD = 3.21$). All other tests were performed before and after the intervention/control condition. Reading comprehension improved after the mindfulness intervention but not after the active control condition (e.g., Fig. 1). Meditators showed more concentration capacity (e.g., Fig. 2) and processed more target objects in the attention test (e.g., Fig. 3) after the meditation intervention.

The LME analyses of the reading speed and comprehension test indicated for the "text comprehension" a significant interaction of "group" and "time". In a subsequent analysis, we discovered a significant main effect for "time" in the MG, but not in the CG. In the analysis of the attention test data, we found a significant interaction of "group" and "time" for "Concentration Capacity" and "Number of Processed Target Objects". The follow-up analyses showed for both scales a significant main effect for "time" in the MG, but not in the CG. The analysis of the emotion experience test revealed significant interactions of "group" and "time" for "Acceptance of one's own Emotions", "Experiencing

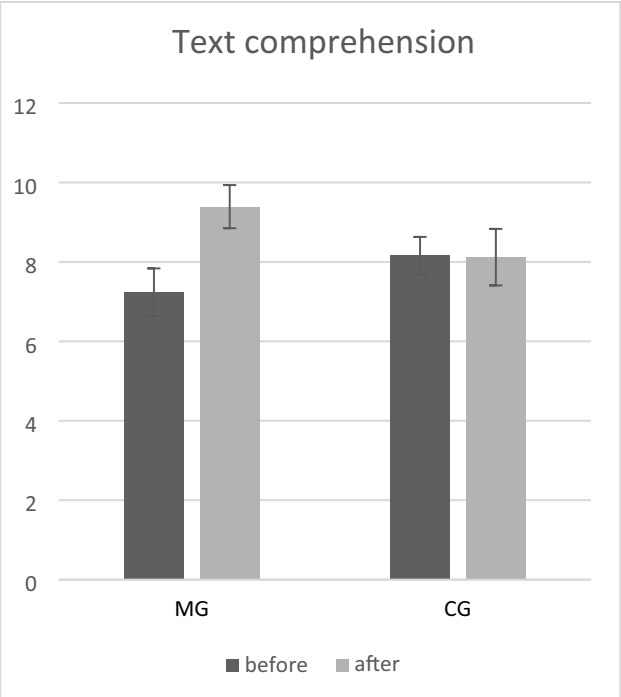

Fig. 1 Results of the reading speed and comprehension test, text comprehension. Error bars indicate standard errors

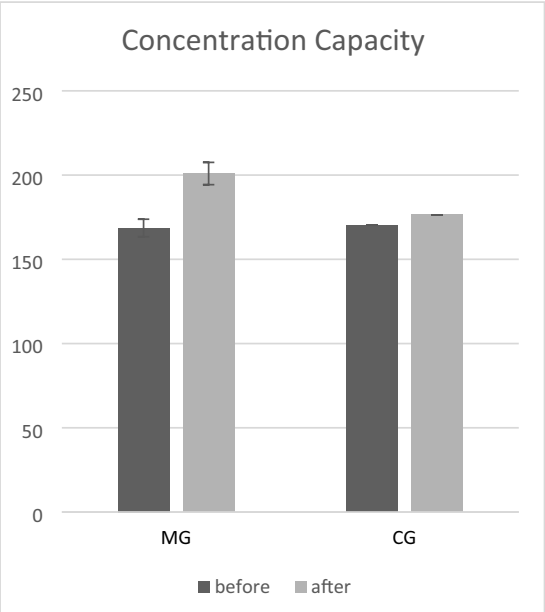

Fig. 2 Results of the attention test, concentration capacity. Error bars indicate standard errors

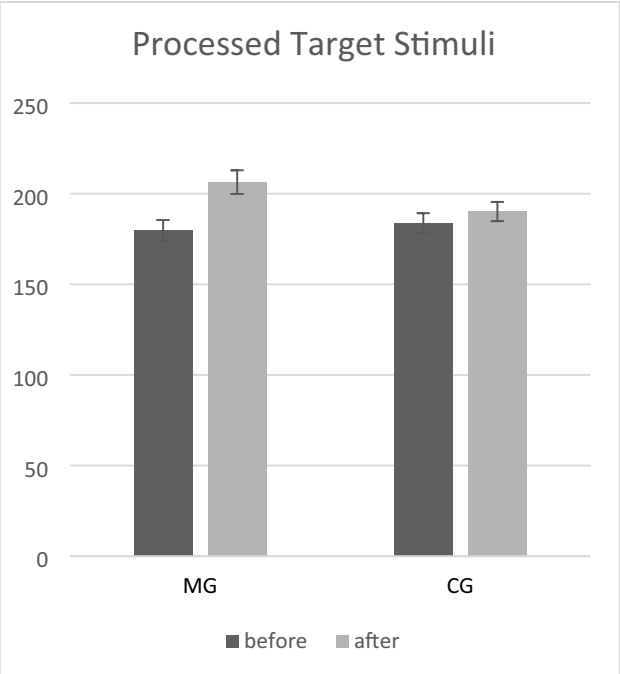

Fig. 3 Results of the attention test, processed target stimuli. Error bars indicate standard errors

Emotion Overload", and "Body-Related Symbolization of Emotions". The subsequent analyses showed for all three scales significant main effects for "time" in the MG, but not in the CG (e.g., Table 2 for results of the overall analyses and Table 3 for the subsequent analyses).

The scales "Concentration Capacity" and "Number of Processed Target Objects" of the attention test and the scales for "Acceptance of one's own Emotions", "Experiencing Emotion Overload", and "Body-Related Symbolization of Emotions" of the emotion experience test changed all significantly after the mindfulness intervention, but not after the active control condition. In further LME analyses, we examined for each of these scales whether they might correlate with the improved reading comprehension in the MG. It turned out that none of the scales of the emotion experience test was associated with reading comprehension, "Acceptance of one's own Emotions" ($B = 0.16$, $SE = 0.31$, $t = 0.51$, $p = 0.61$), "Experiencing Emotion Overload" ($B = -0.11$, $SE = 0.22$, $t = -0.45$, $p = 0.62$), and "Body-Related Symbolization of Emotions" ($B = -0.26$, $SE = 0.22$, $t = -1.19$, $p = 0.24$). Looking at the attention test, both "Concentration Capacity" ($B = 0.06$, $SE = 0.02$, $t = 2.10$, $p = 0.04$) and "Number of Processed Target Objects" ($B = 0.05$, $SE = 0.02$, $t = 2.51$, $p = 0.02$) were positively associated with improved reading comprehension in the MG. Based on these positive associations, we conducted a mediation model to examine whether "Concentration Capacity" or "Number of Processed Target Objects" would mediate the effect of meditation on reading comprehension. Results revealed that neither "Concentration Capacity" ($B = 0.18$, $z = 0.48$, $p = 0.63$) nor "Number of Processed Target Objects" ($B = 0.11$, $z = 0.36$, $p = 0.72$) mediated the effect.

Discussion

In the present study, we found that sustained practice in mindfulness meditation significantly improved reading comprehension. Contrary to our expectations, the meditation intervention did not affect reading speed. No changes in reading comprehension or reading speed were observed in the CG. The MG showed greater acceptance of their emotions, more body-based symbolizations of their emotions, and experienced less emotion overload after the mindfulness intervention. However, these changes in emotion regulation were not positively associated with improved reading comprehension, while the CG did not show any significant differences in emotion regulation. The MG demonstrated enhanced concentration capacity and speed (more targets processed) after meditation intervention. Both scales of sustained attention were positively associated with improved reading comprehension in the MG. However, the analysis of a mediation model showed that enhanced concentration did not mediate the effect of meditation on improved text processing.

Participation in a 6-week mindfulness meditation course resulted in substantially improved reading comprehension. Several underlying mechanisms of meditation may have mediated this effect. There is much evidence that meditation enhances various aspects of attention (Chambers et al., 2008; Semple, 2010; see Lutz et al., 2008 for a review). For example, meditation was found to reduce the Stroop effect (Moore & Malinowski, 2009; Wenk-Sormaz, 2005) and to decelerate binocular rivalry switching (Carter et al., 2005). In the present study, as expected, the ability to concentrate and the number of processed stimuli, as measured by the attention test, were significantly improved after the meditation intervention. Further, both enhanced concentration capacity and the augmented number of processed target objects after meditation intervention were positively associated with improved reading comprehension in the MG. Given that sustained attention is important for successful reading comprehension (Arrington et al., 2014), these results seemed to suggest that improved sustained attention was one of the underlying mechanisms of meditation that contributed to the promotion of reading comprehension in the MG. However, the subsequent mediation model analysis revealed that the effect of meditation on improved reading comprehension was not mediated by either "Concentration Capacity" or "Number of Processed Target Objects".

Table 2 Overall analysis of assessments: estimates of regression coefficients, their standard errors, *t*-values, and *p*-values

Assessments	Fixed effects	*B*	*SE*	*t*	*p*
Reading speed and comprehension test					
Text comprehension	Time	4.34	1.71	2.54	*
	Group	0.92	0.76	1.20	
	Time:Group	−2.19	1.08	−2.02	*
Reading speed	Time	26.69	54.29	0.49	
	Group	−4.44	24.28	−0.18	
	Time:Group	−2.50	34.34	−0.07	
Big Five personality test					
Neuroticism	Time	−1.44	0.65	−2.23	*
	Group	0.09	0.29	0.29	
	Time:Group	0.72	0.41	1.77	
Extraversion	Time	0.33	1.01	0.33	
	Group	0.79	0.45	1.77	
	Time:Group	−0.09	0.64	−0.14	
Conscientiousness	Time	0.46	1.06	0.44	
	Group	0.31	0.48	0.64	
	Time:Group	−0.33	0.67	−0.49	
Agreeableness	Time	0.74	0.83	0.89	
	Group	0.25	0.37	0.68	
	Time:Group	−0.31	0.52	−0.59	
Openness	Time	0.58	0.82	0.71	
	Group	−0.35	0.37	−0.95	
	Time:Group	−0.37	0.52	−0.71	
Need for Power and Influence	Time	0.78	0.92	0.8	
	Group	0.63	0.41	1.53	
	Time:Group	−0.63	0.58	−1.08	
Need for Safety and Peace	Time	0.06	0.89	0.72	
	Group	−0.01	0.39	0.01	
	Time:Group	−0.56	0.56	−0.99	
Need for Achievement and Performance	Time	−0.45	0.87	−0.51	
	Group	−0.22	0.39	−0.55	
	Time:Group	0.14	0.55	0.26	
Attention test					
Number of Processed Target Objects	Time	46.87	13.54	3.46	**
	Group	3.99	8.18	0.49	
	Time:Group	−20.22	8.56	−2.36	*
Concentration Capacity	Time	58.51	13.39	4.37	***
	Group	1.66	8.08	0.21	
	Time:Group	−26.19	8.47	−3.09	**
Percentage of Errors	Time	−6.30	2.98	−2.12	*
	Group	1.45	1.33	1.09	
	Time:Group	2.92	1.88	1.55	
Emotion experience test					
Acceptance of one's own Emotions	Time	2.67	0.72	3.72	***
	Group	−0.26	1.01	−0.26	
	Time:Group	−2.60	1.01	−2.57	*
Experiencing Emotion Overload	Time	−3.65	0.79	−4.60	***
	Group	0.68	1.41	0.48	
	Time:Group	2.45	1.12	2.18	*

Table 2 (continued)

Assessments	Fixed effects	*B*	*SE*	*t*	*p*
Experiencing Lack of Emotions	Time	−1.79	0.82	−2.17	*
	Group	0.54	1.05	0.51	
	Time:Group	1.57	1.16	1.35	
Body-Related Symbolization of Emotions	Time	2.37	0.89	2.63	*
	Group	0.32	1.43	0.22	
	Time:Group	−3.33	1.27	−2.62	*
Imaginative Symbolization of Emotions	Time	0.43	0.71	0.60	
	Group	−0.43	1.36	−0.32	
	Time:Group	−0.96	0.99	−0.96	
Experience of Emotion Regulation	Time	0.43	0.46	0.94	
	Group	−0.69	0.71	−0.96	
	Time:Group	−0.27	0.65	−0.41	
Experience of Self-control	Time	−0.48	0.64	−0.75	
	Group	−0.15	1.17	−0.13	
	Time:Group	0.51	0.91	0.56	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$. "Time", time effect; "Group", group effect; "Time:Group", interaction of "time" and "group"

Table 3 Subsequent analysis of significant interactions from the overall analysis: estimates of regression coefficients, their standard errors, *t*-values, and *p*-values

Assessments	Fixed effects	*B*	*SE*	*t*	*p*
Reading speed and comprehension test					
Text comprehension	MG; Time	2.15	0.62	3.47	**
	CG; Time	−0.04	0.78	−0.05	
Attention test					
Number of Processed Target Objects	MG; Time	26.65	5.74	4.64	***
	CG; Time	6.42	6.35	1.01	
Concentration Capacity	MG; Time	32.31	6.33	5.11	***
	CG; Time	6.12	5.63	1.09	
Emotion experience test					
Acceptance of one's own Emotions	MG; Time	2.67	0.77	3.46	**
	CG; Time	0.06	0.66	0.09	
Experiencing Emotion Overload	MG; Time	−3.65	0.74	−4.89	***
	CG; Time	−1.20	0.84	−1.44	

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$

An individual with a mind that does not get easily agitated and carried away by arising emotions might have advantages in reading comprehension because it should be easier to focus on the content of the text. Several studies found that meditation training can improve the regulation of emotions (Geschwind et al., 2011; Ivanovski & Malhi, 2007). Therefore, we assumed that emotion regulation could be another underlying mechanism of meditation that might lead to enhanced text processing. Lusnig et al., (2020, 2022) showed that meditation can affect single word processing and also neutralize valence ratings on emotional words. However, in the present study, none of the changes in experiencing emotions was positively associated with improved reading comprehension. This may be related to the fact that, unlike in the word recognition studies of Lusnig et al., (2020, 2022), the text materials used in the present work had no affective connotation and did not call for a substantial affective evaluation.

The present study also did not find effects of meditation practice on the Big Five personality traits "openness" and "need for achievement and performance". In the study by Lusnig et al. (2020), adept Zen practitioners demonstrated greater "openness to experience" and lower "need for achievement and performance" compared to non-meditators. It seems plausible that people who choose to meditate by themselves are more open to experiences and have a lower need for achievement and performance. In the present study,

however, individuals participated in the meditation class for course credits. There is also a possibility of differences between effects of Zen practices vs. mindfulness meditation.

For organizational reasons, we could only include assessments on concentration capacity, emotion regulation, and personality traits as covariates. Given that none of these covariates mediated the effect of meditation on improved reading comprehension, it is interesting to discuss other possible underlying mechanisms of meditation that might account for this effect. Reduced mind wandering might be one of these mechanisms. Several studies found that mind wandering while reading distracts the reader and impairs text comprehension (Reichle et al., 2010; Smallwood, 2011). Feng et al. (2013) found that readers especially struggle with mind wandering when reading difficult texts, and that comprehension of these difficult texts is affected by mind wandering. Mindfulness meditation, on the other hand, can be an effective technique for reducing mind wandering. Both short-term and extended mindfulness meditation practices can decrease mind wandering (Mrazek et al., 2013; Rahl et al., 2017). Further, meditation can lead to a diminished activation of the default mode network, which is associated with the wandering of thoughts (Brefczynski-Lewis et al., 2007; Brewer et al., 2011). This evidence suggests that the reduction of mind wandering (via focusing on the primary task) may be an underlying mechanism of meditation that facilitates reading comprehension.

Another important mechanism for successful reading comprehension, that we could not assess, is a good working memory capacity. Daneman and Carpenter (1980) demonstrated that working memory capacity is associated with comprehension in both silent reading and listening. Working memory capacity is thought to be foundational for reading comprehension "because the processing and storage capacity of working memory is important for remembering new information, for making inferences about new information, and for integrating prior knowledge with the new information" (Daneman & Hannon, 2001, p. 28). A meta-analysis of as many as 77 studies on this topic by Daneman and Merikle (1996) supported the view that a good working memory capacity is important for successful language/reading comprehension. Meditation training was found to be a method for enhancing working memory capacity (Mrazek et al., 2013). Even short-term exercises in mindfulness meditation can increase the working memory capacity (Bonamo et al., 2015; Quach et al., 2016). Further, meditation practice can prevent impairments of the working memory capacity in times of high stress (Jha et al., 2010). It should be noted that the meditation practice employed in the present study used mental imagery techniques to facilitate the achievement of mindful states. Even though we have no data to directly support this idea, it might be the case that this reinforced use of mental imagery might have contributed to successful reading for understanding in the MG, as the use of mental imagery was found to improve reading comprehension (Gambrell & Bales, 1986).

Reading speed can be accelerated through specific reading training without significant loss in comprehension (Radach et al., 2010; Roesler, 2021). Response times to single words can be affected by many different word properties, for example, arousal, frequency, or word length (Hofmann et al., 2009; Kuchinke et al., 2007; New et al., 2006) and are also modified by inter-individual differences between readers (Mueller & Kuchinke, 2016; Siegle et al., 2002). As meditation practice was also found to elicit faster single word recognition (Lusnig et al., 2020, 2022), the question arises of whether meditation training can also influence reading speed of whole texts. This research question is mostly unanswered. Rice et al. (2020) found in a pilot study that mindfulness practice can improve the reading speed of servicepersons in the U.S. military. Both single-word processing and the reading of text passages (the sum of the word reading times) were accelerated. However, in the present study, reading speed did not change after the mindfulness intervention, contrary to our expectations. These incongruent results might be explained by the different reading assessments used in the present study and by Rice et al. (2020). In the study by Rice et al. (2020) a self-paced reading task was used, which did not involve reading entire sentences or text passages in a flow. Words were presented one after another on a computer screen, so that response times were possibly co-determined by motor speed and rhythm. In addition, reading comprehension was not measured in their study. It is therefore possible that their meditation group showed increased single word recognition (as in Lusnig et al., 2020, 2022), but at the expense of comprehension. In the present study, reading speed did not accelerate, presumably because the readers also focused on good text comprehension during a standardized reading test, measuring reading for meaning within a certain time limit.

Several studies showed that decoding of single words and semantic processing (of texts) are separate processes (Golinkoff & Rosinski, 1976; Stothard & Hulme, 1995). For example, children, which have reading comprehension difficulties may decode single words well but are significantly weaker in semantic processing than an age-matched control group (Nation & Snowling, 1998). Carroll et al. (2014) found that children who had a family risk of developing dyslexia were significantly more likely to have difficulty with reading accuracy, but were not at higher risk of developing impaired reading comprehension. In a longitudinal study by Oakhill et al. (2003), two different measures of word reading could not explain reading comprehension differences. This could explain why the meditators of the present study demonstrated better reading comprehension but no improved reading speed. These results also fit with the assumption that

meditation increases the depth of information processing (Van Leeuwen et al., 2012). Even though meditators can process single words faster than control participants, this faster single word recognition might not lead to a faster reading performance of texts, because their deeper information processing requires more time. The deeper information processing then might lead to improved reading comprehension.

Limitations and Future Research

The present study reveals some limitations. The sample size was chosen to be similar to a reference study by Mrazek et al. (2013); however, it is relatively small. In the current study, we wanted to conduct post-tests as soon as possible after the intervention/control condition to capture the immediate effects of meditation practice. We chose paper-and-pencil tests because this allowed participants to be tested more quickly in larger groups than with computerized tests. However, especially for the assessment of attentional skills, computerized tests would have been more accurate than the attention test that we had used.

The present study investigated the influence of meditation on reading comprehension and reading speed. Our results suggest that meditation can be a promising technique to improve reading comprehension since meditation is quite easy to learn and can be used everywhere. Based on our results, future studies should utilize more refined methods such as eye tracking to examine the effects of meditation on moment-to-moment processing during reading, along with comprehension on the local and global level (Radach & Kennedy, 2013). A promising candidate for this endeavor is the process of comprehension monitoring, providing a measure of sensitivity towards subtle semantic inconsistencies within text passages (Vorstius et al., 2013). This could provide a possibility to test the hypothesis that skills in mindfulness meditation might have the potential to translate into a deeper and more attentive reading for meaning. Further, future studies on the present topic should consider assessments on mind wandering and working memory capacity, as these may be important underlying mechanisms of meditation that can affect reading comprehension.

Author Contribution Markus J. Hofmann: conceptualization, writing — review and editing, formal analysis, supervision, methodology, project administration. Ralph Radach: conceptualization, writing — review and editing, supervision, methodology. Larissa Lusnig: conceptualization, writing — original draft, data curation, formal analysis, methodology, project administration. All authors read and approved the final version of the manuscript for submission.

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Data Availability All data are available at the Open Science Framework Figshare. (https://doi.org/10.6084/m9.figshare.20311260.v1).

Declarations

Ethics Statement The study, which was conducted for the present article, followed the ethical standards of the Declaration of Helsinki and the German Society of Psychology (DGPs). The Ethics Committee of the University of Wuppertal reviewed the experiment and approved it.

Informed Consent Informed consent was obtained from all participants included in the study.

Conflict of Interest The authors declare no competing interests.

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