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Meditation dosage predicts self- and teacher-perceived responsiveness to an 18-month randomised controlled trial

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Understanding the factors that predict why some individuals perceive to respond more to meditation training than others could impact the development, efficacy, adherence levels, and implementation of meditation-based interventions. We investigated individual-level variables associated with self- and teacher-perceived responsiveness to longer-term meditation training. This study presents a secondary analysis of the Age-Well trial (NCT02977819, 30/11/2016) and includes 90 healthy older adults (65–84 years) that were randomised to an 18-month meditation training or a non-native language (English) training. Responsiveness was measured post-intervention using participants' and teachers' ratings of four psychological domains (connection, positive/negative emotions, meta-awareness) in relation to two contexts (during sessions, in daily life), teachers' perception of overall benefit, and a global composite comprising all self- and teacher-perceived responsiveness measures. Linear regression modelling indicates that, when including baseline variables (sex, education, neuroticism, cognition, expectancy) and engagement (hours of formal practice during intervention), only higher levels of engagement were associated with higher global composite scores (standardised estimate = 0.50, 95% CI: 0.24–0.77, $p < 0.001$). Global composite scores were not correlated with pre-post changes in well-being. Findings indicate that more time spent practising meditation was related to greater perceived intervention effects. We suggest that future studies closely monitor levels of engagement and map reasons for disengagement.

Meditation is a complex umbrella term. Several definitions have been proposed, yet no unifying framework for conceptualising meditation training exists. Nonetheless, important advances have been made in defining and categorising meditation practices[1–5]. Broadly conceptualised, meditation can be viewed as a collection of practices aimed at intentionally training ways of relating to experience that reduce suffering and deepen human flourishing[6–8]. More specifically, these meditative practices can be taxonomised based on their associated psychological mechanisms and phenomenology. For instance, a widely-adopted model differentiates between practices primarily aimed at cultivating meta-awareness (i.e., attentional practices such as mindfulness), practices aimed at increasing the capacity for perspective taking and cognitive reappraisal (e.g., constructive practices such as compassion), and practices aimed at transforming maladaptive patterns of perceiving self, others, and the world (i.e., deconstructive practices such as insight/vipassana;[1]). These theoretical advances have provided a useful vantage point from which to survey the growing number of empirical studies comprising the meditation research literature (for reviews see e.g.,[9,10]).

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Numerous studies have investigated the impact of meditation training on a broad range of psychological and neurophysiological outcomes[11–16]. Amongst the differing types of meditation practice, mindfulness and loving-kindness and compassion practices have received the greatest amount of scientific and media attention[9]. Despite this increased attention on meditation training's putative effects over the past decades, the contemplative research literature is still young and thus characterised by some important gaps[9,17]. For instance, it remains to be further explored if the heterogeneity of effect sizes between studies and the variability within studies is related to the possibility that some participants might be more receptive and sensitive to meditation practice than others.

Responsiveness captures the degree to which participants perceive to benefit from meditation training (i.e., subjective causality attribution) or teachers perceive participants to benefit. This form of subjective causality attribution captures aspects that are not captured by mean changes in meditation-related construct (e.g., mindfulness) from pre- to post-intervention. Why and to what extent do some individuals perceive to respond more to a given meditation practice than others? There are several possible reasons for why a clearer understanding of these questions has accrued only slowly. First, randomised controlled trials (RCTs) of meditation training are primarily used to test between-group differences, i.e., to establish whether a meditation-based intervention is superior to a control group on mean changes in a desired outcome[18,19]. In this context, the assessment of within-group variability in responsiveness to the meditation training is secondary and not required to achieve the primary aim. Second, even if responsiveness to meditation training is assessed in secondary analyses of RCTs, they are often limited to moderator analyses in which baseline variables are used to predict mean changes in the primary outcome or related measures of interest (see e.g.,[20,21]); and seldom directly capture participants' subjective causality attribution (i.e., their subjective perception of the causal link between meditation training and a given outcome). Meta-analytic approaches using aggregate data from RCTs are effective for estimating the magnitude of meditation effects (see e.g.,[18]), but these types of meta-analyses are limited in understanding for whom meditation-based interventions work (i.e., moderation) as they are commonly under-powered and based on study-level data[22]. Meta-analyses with individual participant data would be needed to offer a more fine-grained examination of the differential benefits derived from meditation training, yet they tend to be methodologically and administratively challenging (e.g., regarding clinical trial data access, between-trial data harmonisation, and required time investment). Third, no validated, standardised measures of (self- or teacher-perceived) responsiveness to meditation training have been published; researchers tend to refrain from employing tailor-made questionnaires that have not been independently validated as this makes comparing the findings to other (non-)meditation interventions and interpreting them in the context of the broader research literature more difficult. In the context of the present study, we introduce a responsiveness questionnaire specifically developed for the European Union's Horizon 2020-funded Medit-Ageing European project. Fourth and relatedly, outcomes in RCTs are thus usually drawn from an existing pool of measures to avoid the resource-intensive development of new measures. As the selected measures might not have been specifically developed or selected for assessing responsiveness beyond changes in the desired outcome, the assessment might be limited in range and nature (e.g., only first-person or third-person data).

Existing research and theory have considered and found only few factors that could explain differences in trajectories of intervention response[18]. A consistent pattern seems to be that participants who report better/poorer baseline functioning in a given outcome tend to show smaller/larger increase in this outcome during meditation training (see [33]). This pattern was also observed in two RCTs that our group has conducted, namely the Age-Well trial (one of the longest meditation trials conducted to date including an 18-month meditation training in older adults) and the SCD-Well trial (an 8-week meditation-based intervention in older adults with memory concerns). In the Age-Well trial, higher baseline scores of cognition[23] and psychological well-being[24] predicted smaller improvements in these domains. These findings were mirrored by the SCD-Well trial in relation to well-being[25] and cognition[26]. However, this baseline-outcome dependency might not be unique to meditation training but characteristic of all bona fide interventions that share common factors such as acquisition of new skills, social engagement, and expert support (see[22,27]. Notably, no large-scale RCT of meditation training conducted to date has provided consistent evidence for the opposite pattern in which higher baseline functioning was associated with a more pronounced training response. However, theoretically this option is still worth preserving, because some baseline factors (e.g., higher attentional capacities such as mindfulness) might allow participants to engage more successfully in meditation training, while potentially undetected intervention-related improvements in these capacities might be due to measurement issues, such as ceiling effects, rather than a lack of responsiveness per se (for a discussion of validity concerns surrounding meditation-related measures see e.g.,[9,28]).

Previous work on potential individual differences in responsiveness to meditation training has also considered the role of sex, neuroticism, and engagement with the intervention. Preliminary evidence from short-term interventions in early adolescents and college students suggests that female participants may benefit more from meditation training[29,30], but a systematic review of mindfulness-based interventions in patients with substance use disorder did not provide unequivocal support for this conclusion[31]. In meditation-naïve participants with psychological stress complaints, higher baseline levels of neuroticism were associated with greater decreases in anxiety during an 8-week mindfulness-based stress reduction programme[32]. Regarding intervention engagement, previous theoretical work purported that the efficacy of any legitimate meditation-based intervention is dependent on participants' engagement with and persistence of practice[33], while a meta-regression found no evidence for a relationship between dosage (including session numbers, duration and length, facilitator contact and practice) and psychological outcomes such as depression, anxiety, and stress[34]. Strikingly, data from our two recent large-scale RCTs of meditation training indicated that neither sex, session attendance, daily practice adherence, age, education, neuroticism, nor proxy measures of intelligence consistently predicted psychological or cognitive changes during the interventions[23–26,35,36]. In sum, additional and refined approaches to capturing responsiveness during meditation-based interventions are needed to understand the factors that

influence trajectories of change, which may be non-linear, vary substantially across individuals, outcome domains, and intervention duration, and may be affected by meditation-related difficulties[37–39].

Of particular interest in this regard is the triangulation of intervention-specific measures of self-perceived responsiveness, complementary measures of teacher-perceived responsiveness, and standardised measures of outcomes that, based on theory, should be altered by meditation training, such as the meditation-based well-being dimensions of awareness, connection, insight (see e.g.,[2,40]). The present study attempted to contribute to our understanding of responsiveness to meditation training by investigating these factors. Specifically, we aimed to investigate (i) self- and teacher-perceived responsiveness to an 18-month meditation training, compared to a structurally matched non-native language (i.e., English) training, (ii) the correlations of self- and teacher-perceived responsiveness measures and intervention effects on meditation-based dimensions of well-being, and (iii) the factors (i.e., sex, education, neuroticism, cognition, engagement, and expectancy) that could be predictive of self- and teacher-perceived responsiveness.

Methods

The present study used data from the Age-Well randomised controlled trial of the European Union's Horizon 2020-funded Medit-Ageing European project (public name: Silver Santé Study), whose intervention design, recruitment procedure, eligibility criteria, and assessments have previously been detailed[41]. Here, we present secondary analyses of the Age-Well trial.

Study design

Age-Well was a monocentric, randomised, controlled superiority clinical trial investigating mental health and related outcomes in older adults. The trial included three parallel conditions: a two-module (i.e. mindfulness, and loving-kindness and compassion) 18-month meditation training, a structurally matched 18-month non-native language (i.e., English) training, and a no-intervention control group. Participants in the no-intervention group were asked to refrain from practising meditation or learning a foreign language for the entire intervention period. The three groups were randomised following a 1:1:1 ratio. The primary outcomes of the Age-Well trial (i.e., mean change in volume and perfusion of the anterior cingulate cortex and insula) have been published[35].

Age-Well was carried out in Caen (France). Prior to participation, all participants received an explanation of the procedures and then provided written informed consent. Age-Well received ethics approval from the Comité de Protection des Personnes CPP Nord-Ouest III in Caen (trial registration number: EudraCT: 2016-002441-36; IDRCB: 2016-A01767-44; ClinicalTrials.gov Identifier: NCT02977819, 30/11/2016). Age-Well was sponsored by the Institut National de la Santé et de la Recherche Médicale (INSERM) and performed in accordance with the 1964 Declaration of Helsinki and its later amendments.

Participants

In total, 137 participants were randomised. After randomisation, one participant was excluded because of amyotrophic lateral sclerosis and another participant because of a previous head trauma with loss of consciousness for more than one hour. A third participant died before the trial was completed. Responsiveness data was only collected for the meditation and non-native language training groups. The present study thus used data from 90 cognitively unimpaired, older adults (age range: 65 to 78 years [meditation]; 65 to 84 years [language training]), who were native French speakers, were retired for at least one year, had completed at least seven years of formal education, and had no major neurological or psychiatric disorder, and no present or past regular or intensive practice of meditation (Table 1).

Interventions

Meditation training

The 18-month meditation training incorporated weekly 2-hour group sessions, daily home practice ($\geq$20 min), and a special retreat day with 5 h of dedicated practice. The training was divided into two 9-month modules specifically tailored for Age-Well. These modules aimed to support healthy ageing and provide skill training for meeting the physical and psychological challenges associated with ageing. The initial 9-month module of the intervention focused on the cultivation of mindfulness practices, whereas the latter 9-month module emphasised the training of loving-kindness and compassion practices (for further details see[41].

Non-native language training

The English language training (for French native speakers) consisted of the same format as the meditation training in relation to administration, duration, and dosage of group meetings and home practice. The training comprised exercises focused on improving participants' vocabulary and grammatical skills and their transference to reading, writing, and speaking.

Measures

Meditation training group

To capture responsiveness to meditation training, we used participants' self-rated response to the intervention and teachers' ratings of participants' response to the intervention. Self- and teacher-rated responses were captured post-intervention. A global responsiveness composite score was computed by combining these domains (detailed below).

Participants rated their responsiveness to the intervention using tailor-made scales that captured four domains: connection, positive emotions, negative emotions, and meta-awareness. Connection was described to participants as a feeling of emotional connection, love, empathic resonance with people or a community of people. Meta-awareness was described as awareness of one's thoughts and emotions, and observation of

	Meditation ($n = 45$)	English training ($n = 45$)
Age, years	69.5 (3.7), range: 65 to 78	70.3 (4.5), range: 65 to 84
Female, n (%)	31 (69%)	25 (56%)
Education, years	13.1 (3.1)	12.2 (3.0)
Engagement in meditation during intervention (in hours)	213.7 (101.9)	–
Self-perceived responsiveness – Frequency during session[1]		
Connection	3.8 (0.8)	4.0 (1.0)
Positive emotions	3.4 (0.8)	3.8 (1.0)
Negative emotions (reverse-scored)	4.2 (0.8)	4.2 (0.8)
Meta-awareness	3.4 (1.0)	2.1 (1.2)
Self-perceived responsiveness – Change in frequency in daily life[2]		
Connection	2.4 (1.5)	1.6 (1.7)
Positive emotions	2.4 (1.3)	1.8 (1.6)
Negative emotions (reverse-scored)	1.6 (1.8)	0.7 (1.5)
Meta-awareness	2.4 (1.6)	0.9 (1.1)
Teacher-perceived responsiveness – Change in frequency in daily life[3]		
Connection	2.5 (1.2)	0.5 (0.5)
Positive emotions	2.6 (1.3)	0.7 (0.5)
Negative emotions (reverse-scored)	1.3 (0.8)	-0.1 (0.3)
Meta-awareness	1.9 (0.9)	0.4 (0.4)
Teacher-perceived responsiveness		
$Benefit_{Teacher}$[4]	2.6 (1.2)	-

Table 1. Descriptive statistics. Note. All variables are mean (standard deviation) unless otherwise specified. Negative emotions scores were reverse-scored so that higher scores reflected less negative emotions. [1] Session ratings ("Have you frequently had this kind of experience during the intervention? During or just after a meditation/English training session?") range from 0 (*never*) to 5 (*always*). [2] General/daily life ratings ("Have you noticed a change related to the intervention in the frequency of this type of experience in your life in general?") range from −5 (*much less often*) to 5 (*much more often*). [3] General/daily life ratings ("Based on their behaviour and feedback during the classes, did you notice during the intervention a change related to the intervention in the frequency of occurrence of the following types of experiences in the participant's life?") ranged from −5 (*much less often*) to 5 (*much more often*). [4] Ratings ("Did the participant benefit from the intervention (in relation to what you taught them)?" ranged from 0 (*Not at all*) to 5 (*enormously*).

one's mental life with a certain distance (e.g., thoughts are just 'thoughts'). Post-intervention, the four domains were assessed in relation to two contexts (i.e., participants completed a total of eight questions), namely the weekly group session and daily life (i.e., outside the session). Session ratings ("Have you frequently had this kind of experience during the intervention? During or just after a meditation/English training session?") used a 5-point Likert scale ranging from 0 (*never*) to 5 (*always*). Daily life ratings ("Have you noticed a change related to the intervention in the frequency of this type of experience in your life in general?") used an 11-point Likert scale ranging from −5 (*much less often*) to 5 (*much more often*). Negative emotions scores were reverse-scored so that for each domain higher scores reflected better functioning. We then computed two responsiveness composite scores, one including the scales assessing responsiveness during the weekly group session (hereon called $Session_{Participant}$), the other one during daily life in general ($General_{Participant}$). First, all scale scores were standardised using their mean and standard deviation. Each responsiveness composite score was then computed by averaging the standardised scores of the scales comprising the respective composite, yielding composite scores with a baseline mean of 0 and a standard deviation smaller than one. Lastly, we re-standardised each composite score so that estimates could be directly interpreted in standard deviation units. Session and general ratings were captured at 18 months (i.e., post-intervention).

Teachers rated participants' response to the intervention in the same four domains (i.e., connection, positive emotions, negative emotions, and meta-awareness) in relation to participants' life in general ("Based on their behaviour and feedback during the classes, did you notice during the intervention a change related to the intervention in the frequency of occurrence of the following types of experiences in the participant's life?") using an 11-point Likert scale ranging from −5 (*much less often*) to 5 (*much more often*). Following the same procedure outlined in the previous paragraph, the four domains were combined into a responsiveness composite score ($General_{Teacher}$). Furthermore, a question about how teachers perceived the overall benefit that participants received from the intervention ("Did the participant benefit from the intervention [in relation to what you taught them]?"; from hereon called $Benefit_{Teacher}$) was answered using a 5-point Likert scale ranging from 0 (*Not at all*) to 5 (*enormously*). Teacher ratings were captured at 18 months (i.e., post-intervention). Teachers had only minimal contact to participants outside of the formal weekly meditation session.

A global responsiveness composite score (from hereon called Global-Responsiveness) was computed by combining $Session_{Participant}$, $General_{Participant}$, $General_{Teacher}$, and $Benefit_{Teacher}$ scores. First, the variables were

standardised using the relevant means and standard deviations and then averaged and re-standardised to yield a global responsiveness score with a mean of 0 and standard deviation of 1.

To measure engagement with the intervention, we used the total amount of practice participants engaged in during the intervention, which combined the number of hours that participants formally engaged in meditation practices in class (i.e., 60 min per weekly session and five hours in total for the retreat day) and formal practices outside of class. For the entire duration of the intervention, participants used a homework diary to record the amount of time they spent formally practising meditation each day.

Further, we used a measure of meditation-based well-being that captured, to an equal degree, the well-being dimensions of awareness, connection, and insight. These dimensions are based on the theoretical model developed by Dahl et al.[1,2]. The measure has previously been developed and psychometrically validated (described in[42]) and used in recent intervention studies[24,25,35]. The measure is based on scales or subscales from six self-report measures: the Compassionate Love Scale[43,44], Drexel Defusion Scale[45], 39-item Five Facet Mindfulness Questionnaire (FFMQ)[46], Interpersonal Reactivity Index[47], Multidimensional Assessment of Interoceptive Awareness Questionnaire[48], and the Prosocialness Scale[49]. Detailed descriptions of these measures can be found in Table S1 (Supplementary Material). Here, we used change in meditation-based well-being scores from baseline to post-intervention (from hereon called Δ-Wellbeing). The Δ-Wellbeing score captures changes in standard deviation units.

Non-native language training

In the context of the present study, data from the English training group was primarily used to assess the interpretability and validity of the responsiveness measures of the meditation group. Participants and teachers of the English training completed the same set of measures that were developed and administered to measure responsiveness to meditation training in relation to the domains of connection, positive emotions, negative emotions, and meta-awareness. Thus, the following responsiveness composite scores could be computed that mirrored those in the meditation group: $Session_{Participant}$, $General_{Participant}$, $General_{Teacher}$. The Global-Responsiveness score was not computed as the $Benefit_{Teacher}$ score in the English training group ("Did the participant benefit from the intervention [in relation to what you taught them]?") did not refer to meditation-related capacities.

Statistical analyses

Sample size

Sample size was determined in relation to an anticipated effect size of 0.75, with a power of 80% and a Bonferroni-adjusted two-sided type I error rate of 1.25% for the two primary outcomes of the Age-Well trial (namely, the average change in volume and perfusion of the anterior cingulate cortex from pre- to post-intervention between the meditation and the passive control group). This led to a minimum total of 126 participants (42 in each group), which has been surpassed ($n = 137$; detailed in[41]). Given that the subgroup analyses conducted in the present study only included 44 participants, the present study should be viewed as exploratory and preparatory work for further research on the seldom-investigated question of responsiveness to meditation training, and our results should be interpreted with caution.

Scale and item assessment

In an initial step, distribution and floor/ceiling effects of the responsiveness measures were assessed using visual inspection of the histograms and skewness and kurtosis estimates. Participant and teacher data were not excluded because of very high or low scale scores. Interpretability was assessed by comparing responsiveness between the intervention groups. In comparison to English language training, we predicted meditation training to have a greater impact on the measures that were developed to capture responsiveness to meditation training.

Correlation analysis

The focus of the present study lay on the responsiveness to meditation training. We therefore conducted all correlation and regression analyses within the meditation group only. The relationship between the responsiveness measures was assessed using Pearson's correlation coefficients. We predicted $Session_{Participant}$, $General_{Participant}$, $General_{Teacher}$, $Benefit_{Teacher}$, and Δ-Wellbeing to positively inter-correlate.

Regression analysis

Within the meditation group, we used a linear regression model with Global-Responsiveness scores as the continuous outcome and baseline variables as the predictors. To ensure model stability and avoid overfitting in the context of the small sample size of the meditation group (a total of 44 participants with composite-global data), we restricted ourselves to including only six potential predictors (all are baseline variables except engagement): sex, education, neuroticism (measured by the 44-item Big Five Inventory[50]), cognition (measured by the Preclinical Alzheimer's Cognitive Composite 5[51]), engagement (i.e., total amount of practice during the intervention), and expectancy ("How much do you think will the intervention have positively impacted your well-being after 18 months?", rated on a scale from 0 to 100). Stata/MP version 16.0 and R version 4.0.2 were used for all analyses.

Results

Scale and item assessment

In the meditation group, the composite scores of responsiveness captured a wide range of values and did not display marked floor or ceiling effects. Distributions of the composites scores and the teacher benefit score did not substantially diverge from normality as indicated by visual inspection of the histograms and estimates

Variable	$General_{Participant}$	$General_{Teacher}$	$Benefit_{Teacher}$	Δ-Wellbeing
$Session_{Participant}$	**0.47** (0.21, 0.67)	0.24 (-0.06, 0.50)	0.25 (-0.05, 0.50)	0.13 (-0.18, 0.41)
$General_{Participant}$	-	**0.30** (0.002, 0.54)	**0.32** (0.03, 0.56)	0.15 (-0.16, 0.43)
$General_{Teacher}$		-	**0.91** (0.83, 0.95)	0.06 (-0.24, 0.35)
$Benefit_{Teacher}$			-	0.18 (-0.12, 0.46)
Δ-Wellbeing				-

Table 2. Correlations within the meditation group between measures of responsiveness and their accompanying 95% confidence intervals. Note. Estimates in bold are associated with $p < 0.05$.

	Global-Responsiveness		
Predictor	**Standardised estimate**	**95% Confidence interval**	***p*-value**
Sex (female)	0.25	-0.38 to 0.88	0.428
Education	0.01	-0.09 to 0.12	0.801
Neuroticism	0.01	-0.25 to 0.28	0.931
Cognition	-0.08	-0.37 to 0.21	0.597
Engagement	0.50	0.24 to 0.77	< 0.001
Expectancy	0.22	-0.10 to 0.53	0.17

Table 3. Regression analysis within the meditation group predicting global responsiveness scores. Note. The Global-Responsiveness was computed by combining $Session_{Participant}$, $General_{Participant}$, $General_{Teacher}$, and $Benefit_{Teacher}$ scores. First, the variables were standardised using the relevant means and standard deviations and then averaged and re-standardised to yield a global responsiveness scores with a mean of 0 and standard deviation of 1.

of skewness ($Session_{Participant}$: -0.71; $General_{Participant}$: -0.59; $General_{Teacher}$: -0.44; Global-Responsiveness: -1.05; $Benefit_{Teacher}$: -0.55) and kurtosis ($Session_{Participant}$: 3.23; $General_{Participant}$: 2.92; $General_{Teacher}$: 2.68; composite-global: 4.21; $Benefit_{Teacher}$: 2.64).

Participants in the meditation group compared to those in the English group displayed higher $General_{Participant}$ scores (standardised estimated mean difference = 0.78, 95% CI: 0.38 to 1.17, $p < 0.001$), $General_{Teacher}$ scores (1.53, 95% CI: 1.26 to 1.80, $p < 0.001$), and Global-Responsiveness scores (1.01, 95% CI: 0.64 to 1.38, $p < 0.001$). However, $Session_{Participant}$ scores did not differ between the two groups (0.39, 95% CI: 0.03 to 0.81, $p = 0.066$). Of the subscales comprising the $Session_{Participant}$ scores, only meta-awareness differed between the two groups, with the meditation group displaying higher scores (1.04, 95% CI: 0.69 to 1.41, $p < 0.001$). Descriptive statistics of the subscales comprising the composite scores are displayed in Table 1.

Correlation analysis within the meditation group

Pearson's correlation coefficients of the relationship between the responsiveness measures are reported in Table 2. The strongest correlation was found between $General_{Teacher}$ and $Benefit_{Teacher}$ scores (Pearson's correlation coefficient $r = 0.91$, 95% CI: 0.83 to 0.95, $p < 0.001$). Neither $Session_{Participant}$, $General_{Participant}$, $General_{Teacher}$, nor $Benefit_{Teacher}$ were correlated with Δ-Wellbeing (i.e., changes in meditation-based well-being dimensions from baseline to post-intervention). Global-responsiveness scores were also not associated with Δ-Wellbeing (0.18, 95% CI: -0.13 to 0.45, $p = 0.247$). In a sensitivity analysis that excluded all participants with a $Benefit_{Teacher}$ score of 0 ($n = 3$), the relationship between Global-responsiveness scores and Δ-Wellbeing remained non-significant.

Regression analysis within the meditation group

In a linear regression model that included Global-Responsiveness scores as the outcome and sex, education, neuroticism, cognition, engagement, and expectancy as the predictors (Table 3), only engagement (i.e., total amount of practice) was associated with Global-Responsiveness scores (standardised estimate = 0.50, 95% CI: 0.24 to 0.77, $p < 0.001$). The predictors did not display a notable level of multicollinearity. A sensitivity analysis that additionally included baseline FFMQ total scores as a predictor indicated a similar pattern: engagement was associated with Global-Responsiveness scores (0.50, 95% CI: 0.25 to 0.75, $p < 0.001$) as were FFMQ total scores (0.40, 95% CI: 0.09 to 0.72, $p = 0.013$).

Exploratory post-hoc analyses indicated that greater engagement was correlated with higher $General_{Teacher}$ scores (Pearson's correlation coefficient $r = 0.59$, 95% CI: 0.36 to 0.75, $p < 0.001$) and higher $Benefit_{Teacher}$ scores (0.68, 95% CI: 0.49 to 0.81, $p < 0.001$) but not with participant-rated scores ($Session_{Participant}$: 0.17, 95% CI: -0.13 to 0.44, $p = 0.255$; $General_{Participant}$: 0.21, 95% CI: -0.09 to 0.48, $p = 0.162$).

Discussion

The present study aimed to refine our understanding of the factors that predict whether and to what extent participants respond to meditation training. We employed newly developed measures of self- and teacher-perceived responsiveness in relation to connection, positive/negative emotions, meta-awareness, and overall

benefit from meditation. Our results indicate that these composite scores displayed adequate psychometric properties capturing a wide range of values without showing marked floor or ceiling effects. Participants in both the meditation and the non-native language (English) training group reported post-intervention that, during the weekly sessions, they had frequently experienced a sense of connection, positive emotions, and meta-awareness and seldom negative emotions. The frequency of these experiences during the sessions did not differ between the groups, except for meta-awareness, which was experienced more frequently by participants in the meditation group. We also captured the changes in the frequency of connection, positive/negative emotions, and meta-awareness that participants perceived in daily life during the 18-month intervention. Overall, the meditation group perceived greater beneficial intervention-related changes in daily life than the English group. Similarly, teachers' evaluation mirrored this difference in change in the frequency of connection, positive/negative emotions, and meta-awareness. Taken together, this pattern of findings could imply several conclusions. First, the weekly group sessions of meditation training as well as English learning were experienced as emotionally pleasant and beneficial, yet the translation of these experiences into daily life were substantially more pronounced in the meditation group. Second, the cultivation of meta-awareness might play an important role for turning experiences and states that occurred or were practiced during the sessions into enduring capacities and resources that are available in daily life.

We combined all newly developed composite scores into a single global composite score and used it as the outcome in a regression model in which we included sex, education, neuroticism, cognition, engagement, and expectancy as potential predictors. Strikingly, only engagement showed a significant relationship with responsiveness. In a sensitivity analysis that additionally included baseline mindfulness scores as a predictor, both engagement and baseline mindfulness were associated with responsiveness. Given the conceptual overlap between the utilised mindfulness measure (i.e., the FFMQ) and the meta-awareness domain of our responsiveness measure, this association does not surprise and is in line with previous research indicating the moderating role of baseline mindfulness on meditation-based intervention outcomes[20,21]. In other words, it is possible that the more time that participants had engaged in meditation practice during the 18-month intervention period, the greater they perceived the benefits that were derived from meditation training. Conversely, it may be that participants who already perceived meditation as beneficial early on tended to meditate more subsequently. Our findings contribute to the nascent literature on the role of meditation dosage[52,53].

Notably, exploratory post-hoc correlational analyses of the relationship between engagement and the individual composites comprising the global composite suggested that teacher-perceived benefits are more closely associated with engagement than self-perceived benefits. In sum, these findings suggest that engagement with practice might be an important predictor of responsiveness and that easy-to-administer teacher ratings of participants' overall responsiveness capture much variability and could present a parsimonious complementary measure of self-perceived responsiveness. We suggest that future research aims to closely monitor levels of engagement and map the potential reasons for disengagement in order to improve the efficacy of meditation training for a greater number of participants in meditation-based interventions.

Contrary to our expectations, none of the responsiveness scores were associated with changes in meditation-based well-being from baseline to post-intervention. This is particularly striking given that the 18-month meditation training substantially impacted meditation-based well-being (Cohen's $d = 0.43$,[24]). At the same time, as discussed in the previous paragraphs, the meditation training was evaluated by both participants and teachers as beneficial. The counterintuitive lack of a correspondence between the theory-based well-being dimensions and the responsiveness measures suggests that there is not a direct link between our measures of responsiveness and meditation training-derived benefits as measured and conceptualised here (i.e., meditation-based well-being dimensions;[2,42]). We encourage further efforts to respond to the known limitations of established measures of meditation training-based capacities and mechanisms by introducing new self-report as well as behavioural measures. These measurement-related developments could uncover potential reasons for the surprising absence of a relationship between measures of responsiveness and outcomes that, based on theory, should be impacted by meditation training.

Limitations

This study has several important limitations that need to be appreciated when interpreting our findings. Even though the assessment of responsiveness included a form of subjective causality attribution, we only measured responsiveness to meditation training once, at post-intervention. Therefore, we cannot establish a clear causal direction between level of engagement and responsiveness. Furthermore, the responsiveness questions we utilised were specifically developed for this trial and had not been the result of systematic scale development and validation procedures including independent samples. Despite these measurement concerns, we believe that our questionnaire items' theory-based content validity is sufficient to make the results meaningful. Bias in teachers' responsiveness ratings could have been introduced, because the teachers might have perceived those participants who they saw more often in class to have derived more benefits from the intervention. It is also important to consider the nature of our sample, which consisted of healthy older adults who were highly educated and had not previously practiced meditation regularly in their lives. The responsiveness to meditation training in this age group might differ from younger and demographically more diverse samples. Lastly, although the overall sample size of this trial was reasonably large and the study adequately powered for detecting effects of meditation training on brain health, the within-meditation group regression analysis consisted of only 45 participants. We therefore limited the number of predictor variables in our regression models; yet, a certain likelihood for spurious findings cannot be avoided. Future research with larger sample sizes is needed to replicate and build on our findings.

Data availability

The data that support the findings of this study are available from the Medit-Ageing data access committee but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of the Medit-Ageing data access committee following a formal data sharing agreement (https://silversantestudy.eu/2020/09/25/data-sharing).

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Author contributions

MS: Writing of the original draft, Conception and design of the work, Methodology, Data analysis, Data interpretation, Incorporation of co-author feedback. JG: Conception and design of the work, Methodology, Reviewing the work critically for important intellectual content. SF: Conception and design of the work, Methodology, Reviewing the work critically for important intellectual content. RB: Conception of the work, Reviewing the work critically for important intellectual content. OMK: Conception and design of the work, Methodology, Reviewing the work critically for important intellectual content. FC: Conception and design of the work, Methodology, Reviewing the work critically for important intellectual content. NLM: Conception and design of the work, Methodology, Reviewing the work critically for important intellectual content. GC: Conception and design of the work, Methodology, Reviewing the work critically for important intellectual content.AL: Conception and design of the work, Methodology, Data interpretation, Reviewing the work critically for important intellectual content.

Declarations

Competing interests

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Additional information

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