Association between meditative capacities and cognitive functions in healthy older adults naïve to meditation practice

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The manuscript is published under the reference:

Requier, F., Hendy, A. S., Schlosser, M., Demnitz-King, H., Whitfield, T., Chételat, G., Klimecki, O., Lutz, A., Marchant, N. L., & Collette, F. (2023). Association between meditative capacities and cognitive functions in healthy older adults naïve to meditation practice. *Mindfulness*, 1-13. https://doi.org/10.1007/s12671-023-02077-9

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Abstract

Objectives Aging people experience a slight decrease in their cognitive efficiency, even in the absence of brain pathology. Concurrently, several studies have reported positive effects of meditation practice on older adults' cognitive functioning. This study aimed to assess if dispositional mindfulness (or more generally trait meditation capacities) was associated with better cognition during aging. **Method** We analyzed cross-sectional data from 134 healthy elderly participants enrolled in the Age-Well trial (Age: 69.0 ± 3.8, 61.2% female) using a series of linear regressions. Participants were naïve to meditation practice before inclusion in the study. Three core meditation capacities were assessed: *attentional* related to metacognition/regulation of attention, *constructive* assessing attitudes towards others or towards ourselves, and *deconstructive* focusing on cognitive defusion. Cognitive abilities were assessed through four composite measures of attention, executive function, episodic memory, and a global composite sensitive to subtle age-related cognitive changes linked to dementia risk (Preclinical Alzheimer's Cognitive Composite [PACC5]). **Results** There was a positive relationship between PACC5 and deconstructive capacity ($Rsp^2=.03$; $p=.04$). However, no association was observed between the three meditation capacities and the three specific cognitive scores ($p>.05$). **Conclusions** We propose that deconstructive capacity, associated with self-inquiry and down-regulation of maladaptive affective schemes, could be a cognitive factor important for global cognition in healthy aging. It remains to be determined to what extent explicit training in meditation positively influences these capacities and whether these changes also contribute to better cognition in aging. **Preregistration** NCT02977819 (https://ClinicalTrials.gov).

Keywords: meditation; aging; cognition; personality; affective state

Based on United Nations predictions (2019), by 2050, 1/6 people in the world will be over 65, compared to 1/11 in 2019. This increase in life expectancy requires the promotion of healthy aging at physical, psychological, and cognitive levels. It is now well established that even in the absence of brain pathology, aging is associated with subtle declines in cognitive functioning and efficiency in the domains of memory, attention and executive processes (Craik & Salthouse, 2000). However, cognitive decline rates and trajectories are characterized by great variability (Olaya et al., 2017; Rönnlund et al., 2005) and do not necessarily lead to dementia (Qiu & Fratiglioni, 2018). The heterogeneity in cognitive aging profiles can be explained by the coexistence of adverse and protective factors at the biological and psychological levels (Park & Reuter-Lorenz, 2009; Reuter-Lorenz & Park, 2014). Cognitive decline might be influenced by education (Fratiglioni & Wang, 2007; Meng & D'Arcy, 2012), employment complexity and autonomy (Then et al., 2014), physical activity, engagement in cognitively demanding leisure activities and/or sustained social interactions (Wang et al., 2012). Similarly, negative affect including depression, anxiety, rumination, and worry are associated with cognition in aging even at subclinical levels (Dotson, 2014; Marchant et al., 2020).

In this context, it has been proposed that mindfulness meditation might be a useful approach to prevent or delay age-related cognitive decline (Gard et al., 2014a; Reuter-Lorenz & Park, 2014). Indeed, meditation practice positively affects brain functions and structures relevant to cognition, which could, therefore, enhance various cognitive processes, including attention, memory, and executive function (Chiesa et al., 2011; Tang et al., 2015). However, the benefit can sometimes be specific to subprocesses, for example regarding executive functioning (Gallant, 2016). With regard to the aging effects, cross-sectional studies on expert meditators revealed that they have higher levels of fluid intelligence (Gard et al., 2014b), as well as attention and executive function compared with non-meditators (Prakash et al., 2012; Sperduti et al., 2016), and also a younger brain age (Luders et al., 2016). Moreover, intervention studies reported improvements in memory, attention, and executive function after short-term training of older people naïve (i.e., without previous experience) to meditation practice (Gallant, 2016; Gard et al., 2014a) and in patients at risk of or diagnosed with dementia (Innes et al., 2017; Newberg et al., 2010). A recent meta-analysis supported these results by showing a positive effect of mindfulness-based programs on executive function in older adults ($\geq$ 60 years) (Whitfield et al., 2021).

Even if participants do not formally have a meditation practice, dispositional mindfulness could also be a protective factor for cognitive aging. Dispositional mindfulness is defined as the tendency to engage in receptive attention to and awareness of current experiences with non-judgment and acceptance (Baer et al., 2006; Kabat-Zinn, 2003). Several studies reported that dispositional mindfulness seems to increase with age (Boekel & Hsieh, 2018; Prakash et al., 2015), and this rise in mindfulness could partially account for lower negative affect levels (Raes et al., 2015) also seen to decrease with age (Jensen et al., 2020). However, at this time, very few studies have investigated the relationship between mindfulness dispositions and cognition in older adults.

Prakash et al. (2015) assessed the associations between interference resolution in various cognitive tasks (working memory, inhibition, flexibility) and dispositional mindfulness assessed via the Mindful Attention and Awareness Scale score (MAAS; Brown & Ryan, 2003). They failed to observe a positive link between dispositional mindfulness and their attentional control / interference resolution measures among either young or older adults. However, in another study using the same assessment of dispositional mindfulness, Fiocco and Mallya (2015) showed that cognitive flexibility (assessed by part B of the Trail Making Test) was positively associated with the MAAS score in older adults, while no association was found with episodic memory. Finally, Fountain-Zaragoza et al. (2016) observed that the MAAS score was positively associated with reactive attentional control during a continuous performance task, but not during a Go/No-go task, and was not associated with proactive control or with variability in response times. Dispositional mindfulness was measured in these studies with the MAAS, a scale referring to mindfulness as a unidimensional construct based mainly on attentional capacities (Brown & Ryan, 2003). However, the term mindfulness, and more generally meditation, refers to a wide variety of contemplative practices, and meditation can be considered a family of complex emotional and attentional regulatory strategies which allow the cultivation of well-being and emotional balance (Lutz et al., 2008).

A recent taxonomy has been proposed to categorize meditation practices into attentional, constructive and deconstructive families (Dahl et al., 2015). These categories are theoretically informed by their primary cognitive mechanism, consequently the main mechanism of one family can also be cultivated by and/or be necessary for meditation practices in other families, leading to some overlap in processes between families. In short, practices in the attentional family (for example, mindfulness-based practices) systematically train the ability to initiate, direct, and sustain attentional processes and to be aware of thoughts, feelings, and perceptions (i.e., meta-awareness). These abilities are systematically trained in mindfulness-based practices. Practices in the constructive family (for example, compassion and loving-kindness practices) cultivate and strengthen cognitive and affective patterns that positively impact well-being. Perspective-taking and cognitive reappraisal are the core cognitive mechanisms of constructive practices. The deconstructive family (for example, Vipassana or insight practices) consists of analytical and object-oriented meditation. The aim is to weaken and dissolve maladaptive cognitive patterns by investigating the emotional, cognitive, and perceptual dynamics of lived experience (or self-inquiry) and to cultivate insights into the nature of all phenomena. For instance, a standard self-inquiry/ insight consists of dissecting the experience of pain into its component parts while noticing how the associated thoughts, feelings, and physical sensations are constantly changing (Zorn et al., 2020). Empirical evidence in support of the three types of meditation practice comes notably from neuroimaging data showing that meditation practices related to each family induced distinct spatial neuroplasticity in brain areas associated with the core cognitive processes trained by these practices (Valk et al., 2017).

According to this recent taxonomy proposed by Dahl et al. (2015), the use of global scales such as the MAAS (Brown & Ryan, 2003) might not capture specific processes associated with different meditation practices. To go beyond this limitation, we recently defined a three-dimensional dispositional meditation trait (Schlosser et al., 2022). Based on a series of psychometric questionnaires, we computed three dispositional meditation scores corresponding to the attentional, constructive and deconstructive types of practice described in Dahl et al. (2015). These dispositional meditation traits, when assessed in participants naïve to meditation, may reflect their cognitive predisposition to engage with each of these three families of meditation. Determining the influence of such dispositional meditation traits on cognition in aging is particularly relevant in the context of models proposing that multiple psychological factors influence the rate of cognitive changes (Reuter-Lorenz & Park, 2014).

In that context, attentional practices could be associated with a better cognition regarding a recent meta-analysis reporting a positive impact of mindfulness-based interventions on attentional and executive functions in aging (Whitfield et al., 2021). Moreover, we recently argued that constructive and deconstructive practices can indirectly impact cognitive reserve by enhancing positive emotions and by down-regulating detrimental age-related factors, such as stress, or depression (Lutz et al., 2021). For instance, constructive practices such as loving-kindness and compassion were shown to alleviate social stress with a different mechanism than attentional-based meditation (Engert et al., 2017) and deconstructive practice seemed to reduce depressive episodes by learning to cognitively decenter from ruminative thoughts (Segal et al., 2019). These results are particularly interesting as previous studies have shown that anxiety, depression and neuroticism levels are associated with cognitive performance in aging (Bunce et al., 2012; Luchetti et al., 2016)

We capitalized on cross-sectional data from the Age-Well trial in the "Silver Santé Study" (https://silversantestudy.eu/) to test whether dispositional meditation traits are associated with better cognitive functioning in older healthy participants naïve to formal meditation practice along different cognitive domains (memory, attention, executive function) as well as on a global composite considered as a relevant measure to assess risk of dementia in aging (Preclinical Alzheimer's Cognitive Composite [PACC5]; Lu et al., 2019; Mormino et al., 2017). We predicted that the attentional practice would be most associated with cognitive performance. We further expected that constructive and deconstructive practices could show similar, but weaker, associations with cognitive performance. In a second exploratory analysis, we included measures of affective state and personality using self-report scales as mediators to observe if they could have an influence on the relationship between meditation scores and cognitive performance.

Method

Participants

According to the power analysis on G*Power (Faul et al., 2007), with a power level of 80% and an alpha at p=.05 on a linear regression including three predictors, a medium effect size (f=0.25) is expected with 48 participants, and a small effect size (f=0.15) with 77 participants. The final sample consisted of 134 cognitively unimpaired older adults (age range: 65 to 84 years old; one participant was excluded for missing data, flow diagram is in Figure 1) from baseline visit of the Age-Well randomized clinical trial of the European Union's Horizon 2020-funded Medit-Ageing European project (public name: “Silver Santé Study”; Poisnel et al., 2018). The study has been registered on Clinicaltrials.gov (NCT02977819). A lack of previous experience with meditation training was a requirement for enrollment in the study. Participants were community-dwelling native French speakers (61.19% women), retired for at least one year and with at least seven years of education (demographic information is presented in Table 1). The Montgomery and Asberg Depression Rating Scale (MADRS; Montgomery & Asberg, 1979) was used as an eligibility criterion, and participants who obtained a score above 7 were excluded. None of the participants reported recent history of neurological or psychiatric disease (including alcohol or drug abuse) or taking medication likely to affect the central nervous system. Finally, all had normal or corrected-to-normal vision and hearing, and obtained a score superior to 27 on the Mini Mental State Examination (Folstein et al., 2001). All participants gave their written informed consent to enter the study.

< Table 1 and Figure 1 about here>

Procedure

This study was a monocentric (location at Caen; France) randomized, controlled clinical trial. Participants were included in one of the three groups: meditation training, non-native language training and no-intervention. After a prescreening interview, eligible participants were enrolled for a baseline pre-intervention visit. The mid and last intervention visits were performed 9 and 18 months after the start of the intervention, respectively. Behavioral, biological and neuroimaging data were collected at the three visits. Clinicians were blinded to group intervention and all the data were pseudonymized. Data analyzed here are scores obtained on cognitive tests and on meditation questionnaires at the baseline visit. The cognitive tasks were administered by neuropsychologists and the questionnaires were filled in by participants themselves.

Measures

Cognitive assessment. The cognitive assessment consisted of a comprehensive battery of the French versions of neuropsychological tests assessing short-term and episodic memory, attentional and executive function. Composite scores were created and used for statistical analyses because, compared to individual tests, they possess higher sensitivity, might be less susceptible to floor and ceiling effects and reduce statistical multiplicity. Three composite scores corresponding to the memory, executive function and attentional domains were created based on previous categorizations made in the literature (Bangen et al., 2010; Ossenkoppele et al., 2012). We also created a global score (the Preclinical Alzheimer's Cognitive Composite 5 score; PACC5 score) sensitive to subtle cognitive changes linked to dementia risk (Donohue et al., 2014; Papp et al., 2017). The scores were computed with the same method as previously reported (e.g., Papp et al., 2017).

All cognitive composite scores were computed by averaging scores of each neuropsychological test (the tests were previously standardized) using the mean and standard deviation of the entire group (Z-scores). Thereafter, the composite scores were re-standardized (divided by the standard deviation of the composite). The episodic memory score (Cronbach's $\alpha = .82$ and McDonald's $\omega = .84$) was computed by averaging the standardized scores of the California Verbal Learning Test (CVLT-II; Poitrenaud et al., 2007; three raw scores: (a) sum of five free recalls from learning trials, (b) short-term free recall, (c) long-term free recall) and Logical Memory (Wechsler, 2008; two raw scores: (a) immediate recall (b) delayed recall). The executive function score (Cronbach's $\alpha = .67$ and McDonald's $\omega = .67$) was computed by averaging the standardized scores of Digit Span backward (Wechsler, 2008; raw score), Trail

Making Test part B (Godefroy, 2008; response time), Stroop interference index (Godefroy, 2008; response time for interfering-neutral items), and Letter Fluency (Godefroy, 2008; raw score). The attention composite score (Cronbach's α = .58 and McDonald's ω = .61) was computed by averaging the standardized scores of the Trail Making Test part A (Godefroy, 2008; response time), Stroop naming (Godefroy, 2008; response time), Digit Span forward (Wechsler, 2008; raw score), and Coding (Wechsler, 2008; raw score). Trail Making Test and Stroop scores were reversed so that higher individual scores and therefore higher total compound score indicate better performance. The PACC5 score (Cronbach's α = .60 and McDonald's ω = .61) (Donohue et al., 2014; Papp et al., 2017) was computed as the average of z-scores of the following cognitive measures: long-term free recall of the CVLT-II (raw score), delayed recall of the Logical Memory Test (raw score), total score of the Coding (raw score), Verbal Fluency raw score for the animal category and total raw score of the Mattis Dementia Rating Scale (GRECO, 1994). Raw data are presented in Supplementary Table S1.

Dispositional meditation assessment. A series of psychological self-report scales aimed to assess behavioral aspects and cognitive processes associated with meditation practice was administered to the participants: Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012), 15-item Five Facet Mindfulness Questionnaire (FFMQ-15; Baer et al., 2012), Drexel Defusion Scale (Forman et al., 2012), Interpersonal Reactivity Index (IRI; Davis, 1983), Compassionate Love Scale (Raes et al., 2011) and Prosocialness (Caprara et al., 2005).

The development of the meditation composite scores was based on a theoretical framework categorizing meditation practices into attentional, constructive, and deconstructive types based on the cognitive mechanisms these practices primarily target or necessitate (Dahl et al., 2015). A high value on a composite score is postulated to be associated with a frequent recruitment of the psychological processes associated with that meditation type. A detailed description of the composite development process has previously been published (Schlosser et al., 2022). In short, three of the authors with scientific expertise in the domain (AL, MS, OK) independently assigned items from the questionnaires to the attentional, constructive or deconstructive families based on the cognitive mechanisms they were judged to primarily capture. Inadequate scales or subscales without clear links to the three families were excluded and any disagreement was resolved via group discussion. The meditation composites displayed adequate psychometric properties in three independent samples: meditation-naïve healthy older adults from the Age-Well trial (*n* = 135; Poisnel et al., 2018), meditation-naïve older adults with subjective cognitive decline from the SCD-Well trial (*n* = 147; Marchant et al., 2018), and healthy long-term meditators (≥ 10,000 h of practice including one 3-year meditation retreat) from the Brain & Mindfulness project (*n* = 29; Abdoun et al., 2018). Confirmatory factor analyses on the Age-Well sample corroborated the theoretically predicted distinction between the three meditation families.

The attentional capacity of meditation (corresponding to metacognition / regulation of attention processes) was primarily captured by five items from the MAIA (Noticing, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening) and two items from the FFMQ (Observing, Acting with Awareness) (Cronbach's $\alpha = .72$ and McDonald's $\omega = .75$). The constructive capacity (corresponding to positive attitudes toward oneself and others) was primarily captured by two items from the IRI (Perspective Taking and Empathic Concern) and scores on the Compassionate Love Scale and Prosocialness scale (Cronbach's $\alpha = .46$ and McDonald's $\omega = .49$). The deconstructive capacity (namely self-inquiry and cognitive defusion) was judged to be primarily captured by Personal Distress item from the IRI, two items from the FFMQ items (Non-Judging, Non-Reactivity), and the total score on the Drexel Defusion Scale (Cronbach's $\alpha = .36$ and McDonald's $\omega = .39$).

Each composite score was computed following the same procedure as was used to create the cognitive composite scores. Raw data are presented in Supplementary Table S2.

Affective and personality assessment. We also assessed affective state and personality using self-report scales, as previous studies have shown that anxiety, depression and neuroticism levels are associated with cognitive performance in older adults (Bunce et al., 2012; Luchetti et al., 2016). Depressive symptoms and trait anxiety were assessed with the Geriatric Depression Scale (Yasavage & Sheikh, 1986) and the part B of the State-Trait Inventory form (Spielberger et al., 1970). Neuroticism was assessed by the Big Five Inventory (Plaisant et al., 2010). Raw data are presented in Supplementary Table S3.

Data Analyses

We used linear regression analyses (PROC GLM) to model the relationship between meditation capacities and each cognitive score. Data were normally distributed, and collinearity was assessed using Tolerance (TOL > .10) and Variance Inflation Factors (VIF < 10). We employed separate models for each cognitive score (attention, executive function, episodic memory, and PACC5). In these models, the predictors were the three capacities of meditation, and the dependent variable was each cognitive score. We added the semi-partial R-square (R_{sp}^2) when a significant effect was found. Indeed, semi-partial R-square is useful to explain an effect of one predictor specified in a model with many predictors. No correction for multiple comparisons were applied as this was considered an exploratory study because there is scant data in this research field.

Next, we performed an exploratory mediation analysis (Structural Equation Model [SEM] using the Lavaan package in R) to determine the respective contribution of the predictors identified in the regression analyses to cognitive performance. We included in the model affective/personality and demographic variables that were correlated with the meditation scores (PROC CORR).

Statistical analyses were performed with SAS 9.4 for Windows (SAS Institute Inc., 2013, https://www.sas.com). The exploratory analysis and the graphics were computed with R version 3.6.3 (R Core Team, 2020). The statistical threshold was set at $p < .05$.

Results

Associations between Demographic Variables, Affective State and Personality Trait and Meditation Capacities

We assessed the presence of significant correlations between demographic variables (age and education), affective state, neuroticism level, and dispositional meditation traits associated with the attentional, constructive, and deconstructive families (Table 2). No significant associations were observed between age and meditation scores. Regarding the association with affective state and personality (depression, anxiety, and neuroticism), we found a negative association between anxiety and some meditation capacities (attentional and deconstructive families), while depression and neuroticism were negatively associated with the deconstructive capacity only. Correlations between affective measures are presented in supplemental material.

< Table 2 about here>

Relationships between Cognition and the Three Meditative Capacities

No associations with attentional, constructive, and deconstructive meditation capacity were found for the episodic memory, executive function, and attentional cognitive domains (all p's>.05, Table 3). However, a positive association between global cognition (PACC5) and deconstructive capacity was observed (Rsp^2=.03; p=.04), but no association with attentional and constructive capacity (Table 3, Supplemental Figure S4).

< Table 3 about here>

Affective State and Personality Traits as mediators of the Relationship between Global Cognition and Meditative Capacities

We performed exploratory analyses to determine if the effect of deconstructive meditation we observed on global cognition (PACC5) was mediated by affective state and personality. We included in the model the depression, anxiety and neuroticism scores, and the three meditation capacities. The model (Figure 2, Table 4) had a good fit (CFI=0.98, TLI=0.94, RMSEA=0.07, SRMR=0.05). Positive associations were observed between all affective measures. There was also a significant positive association between deconstructive and attentional meditation capacities. Moreover, the deconstructive capacity had a large negative effect on depression, anxiety and neuroticism values. As expected from our previous regression analyses, we observed a significant positive effect of deconstructive capacity on global cognition (direct effect, in purple in the Figure 2). However, there was no direct effect of attentional capacity, constructive capacity, anxiety or depression on global cognition score, while a significant positive effect of neuroticism was observed. Among the three indirect effects (the effect of deconstructive mediated by the anxiety, depression and neuroticism, respectively in blue, green and red in the Figure 2), only the indirect effect of neuroticism was significant. To summarize, the model is appropriate to use and the mediation analysis showed that neuroticism and deconstructive scores have an impact on global cognitive performance (assessed with PACC5), with neuroticism partly mediating the effect of deconstructive practice.

< Figure 2 about here>

< Table 4 about here>

Discussion

Our study aimed to investigate the relationship between trait meditation reflecting mechanisms involved in attentional, constructive and deconstructive practices (Schlosser et al., 2022) and cognition in aging. In partial agreement with our hypotheses, we observed a positive association between deconstructive capacity and PACC5 score, assessing risk of dementia in aging. In the exploratory mediation analysis, when affective and personality variables were simultaneously considered, our model showed that neuroticism influenced PACC5, and partly mediated the effect of the deconstructive capacity. No associations between any of the meditation capacities and cognitive scores of attention, episodic memory and executive function were observed.

These results suggest that trait meditation capacities, and more particularly deconstructive mechanisms, are associated with cognitive performance in healthy aging. This relationship was observed with the PACC5, a measure sensitive to early amyloid-beta-related cognitive decline (Donohue et al., 2014; Papp et al., 2017), rather than the cognitive composites measuring memory, attention or executive function. The PACC5 is associated with age-related changes and possible dementia prodromes, such as amyloid deposition (Donohue et al., 2014), tau accumulation (Hanseeuw et al., 2019), and lower functional connectivity (Buckley et al., 2017). It is worth mentioning that most studies do not find cross-sectional differences in PACC5 between at-risk/lower-risk groups (Donohue et al., 2014), so we might also expect to observe no associations. However, our finding indicates that deconstructive meditation capacity may be an important protective factor. In line with our results, Strikwerda-Brown et al. (2022) showed that trait mindfulness is associated with less decline on a global measure of cognition and less tau and amyloid-beta brain deposits. They further reported that the nonjudging and non-reactivity components of their mindfulness measure (the FFMQ) were significant predictors of global cognitive decline. These findings strongly align with our own, considering that nonjudging and non-reactivity formed part of our deconstructive composite.

The deconstructive family of meditation practice implicates meta-cognitive processes and self-reflection (Dahl et al., 2015; Schlosser et al., 2022). Deconstructive practices involve inquiries into the nature of thought, perception, and other cognitive and affective processes. Interestingly, self-reflection has been associated with better global cognition in older age (Demnitz-King et al., 2022). Furthermore, individuals with greater deconstructive capacity may be more able to distance themselves from negative thoughts and emotions. Accordingly, several studies have shown a positive effect of meditation practice on rumination (Wolkin, 2015). In a study that included 1281 meditators with 2 to 13 years of practice, a greater meditation experience was associated with less repetitive negative thinking (Schlosser et al., 2020); and separately, higher levels of repetitive negative thinking have been associated with cognitive decline in older age (Marchant et al., 2020). Together these findings suggest that deconstructive meditation capacity may be associated with better cognition via engagement in different thinking styles (higher self-reflection, lower rumination), however this remains speculative because no study has yet examined these specific associations. More generally, Wolkin (2015) proposed that the positive effect of meditation on rumination is a two-step process entailing first distraction and secondly decentering. Decentering is enabled through enhanced metacognition to allow a thought to become a mental event rather than an intrinsic part of the self (Wallace & Shapiro, 2006).

We did not find a mediating effect of anxiety or depression on the relationship between deconstructive trait capacities and performance on the PACC5. We posit that this absence of effect may be due to our participant population. To be eligible for the study, participants could not have significant anxious or depressive symptoms, which could lead to reduced variance on these affective measures. However, the relationship we observe between deconstructive capacity and better performance on PACC5 is mediated by neuroticism level. Namely, lower deconstructive capacity was associated with greater neuroticism, and greater neuroticism with better performance. Interestingly, our data hint that reinforcing a disposition to deconstructive meditation practice could have a positive influence on a personality trait associated with increased dementia risk. However, the observation that higher neuroticism was associated with better cognitive performance contradicts previous data showing that neuroticism is a risk factor for dementia (Neupert et al., 2008; Terracciano et al., 2017). One possible explanation would be that a high cognitive functioning can be linked to perfectionism and therefore negative affect or neuroticism (Chang, 2000). Further, self-reflection has been positively associated with neuroticism (Creed & Funder, 1998; Trapnell & Campbell, 1999), yet it has also been associated with better global cognition and brain function (Demnitz-King et al., 2022). Therefore, there may be a complex interplay between certain correlates of neuroticism (e.g., self-reflection) and cognition.

However, our main prediction was that high scores on measures associated with the attentional family would be related to better cognition, but the association was not observed with our sample. This prediction was based on previous studies that showed that meditation programs centered on attentional processes such as Mindfulness-Based Stress-Reduction led to increases in some aspects of cognition, even after a short training. Indeed, a systematic review and meta-analysis showed a greater improvement in executive functioning and working memory performance in mindfulness-based practice groups, compared to control groups, while no difference was found concerning attention or episodic memory outcomes (Whitfield et al., 2021). Additionally, expert meditators have been shown to recruit attentional processes very efficiently (Brefczynski-Lewis et al., 2007). Here, we explored the correlates of meditation traits in older adults with no experience of formal meditation practices. It thus seems plausible that the dynamics between these informal meditation capacities and cognition differ from those observed after explicit and formal practice. Moreover, we used a compound attentional score while in previous studies, such associations were observed between very specific attentional measures and a global measure of meditation (the MAAS scale) (Fiocco & Mallya, 2015; Fountain-Zaragoza et al., 2016; Prakash et al., 2015). Finally, whilst we did not observe an association between the attention meditation composite and cognition in this study, it is possible that a relationship would be observed after meditation training and in meditators. We argue this on the basis that, in the context of meditation practice, psychological processes reflecting different composites could strengthen one another (Dahl et al., 2015; Lutz et al., 2021). These evolving inter-relationships might then result in a different correlation structure with the meditation composites and cognition (Schlosser et al., 2022).

Limitations and Future Research

A limitation of this study is that it is cross-sectional and therefore causality cannot be determined. We report possible cognitive dispositions for psychological processes important in meditation, and not meditative skills *per se.* Consequently, it remains to be determined to what extent explicit training in meditation practice is linked to changes in dimensional dispositional meditation traits (Schlosser et al., 2022) and cognitive performance. However, the factors that were identified as contributing to the cognitive reserve capacity (and are consequently protective factors against dementia; Dekhtyar et al., 2015) exert their influence over long time periods (e.g., education or occupation), and it is reasonable to expect that a long-term engagement in meditation (that is by formal or informal practice) will be required to yield lasting effects. Furthermore, the responses given by the participants on questionnaires of meditation could be biased by participant's or examinator's characteristics. Indeed, Podsakoff et al. (2012) reported different bias linked to subjective measures such as social desirability, response styles and priming effect. Another potential limitation is the absence of correction for multiple comparisons in the regression models; our approach was to transparently report the number of analyses performed particularly given that this was an exploratory study. Future replication of these results is thus required.

In conclusion, the current study supports the idea that the informal development of trait meditation capacities related to the deconstructive family is associated with a higher level of global cognitive functioning during late life. Moreover, it shows that the benefit of such an attitude could partly depend on personality traits (e.g., neuroticism). The interest of meditation practice as a non-pharmacological intervention to promote healthy cognitive aging is developing. Future studies should determine if the positive effect of an informal meditation attitude on cognition in aging observed here is magnified through intervention implementing formal meditation practice. If a positive effect is confirmed, it should be determined which intervention programs (possibly combining different families of practice appear the most appropriate).

Declarations

Conflicts of Interest

GC has received research support from the EU's Horizon 2020 research and innovation programme (grant agreement number 667696), Fondation d'entreprise MMA des Entrepreneurs du Futur, Fondation Alzheimer, Programme Hospitalier de Recherche Clinique, Région Normandie, Association France Alzheimer et maladies apparentées and Fondation Vaincre Alzheimer (all to Inserm), and personal fees from Inserm, Fondation Alzheimer and Fondation d'entreprise MMA des Entrepreneurs du Futur.

Funding/Support

The Age-Well is a part of the Medit-Ageing project funded through the European Union in Horizon 2020 program related to the call PHC22 “Promoting mental well-being in the ageing population” and under grant agreement No667696. FC is supported by the F.R.S.-FNRS-Belgium. The funders and sponsor had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; and decision to submit the manuscript for publication.

Ethics Statement

After a description of the study’s procedures to the participants and before any data acquisition, written informed consent were signed by participants. The Age-Well trial received ethics approval from the Comité de Protection des Personnes CPP Nord-Ouest III in Caen (trial registration number: EudraCT 2016-002441-36).

Author’s Contributions

Florence Requier: wrote the first draft of the manuscript; statistical analysis; interpretation of data; and incorporation of manuscript feedback. Anne Sophia Hendy: statistical analysis; interpretation of data. Marco Schlosser: substantial contributions to the analysis of data; and revision of the manuscript for important intellectual content. Harriet Demnitz-King: substantial contributions to the analysis of data; and revision of the manuscript for important intellectual content. Tim Whitfield: substantial contributions to the analysis of data; and revision of the manuscript for important intellectual content. Gael Chételat: substantial contributions to the conception of the work; and revision of the manuscript for important intellectual content. Olga Klimecki: substantial contributions to the design of the work; and revision of the manuscript for important intellectual content. Antoine Lutz: substantial contributions to the conception and design of the work; interpretation of data; and revision of the manuscript for important intellectual content. Natalie L. Marchant: substantial contributions to the conception and design of the work; interpretation of data; and revision of the manuscript for important intellectual content. Fabienne Collette: substantial contributions to the conception and design of the work; contributions to writing the first draft of the manuscript; interpretation of data; and revision of the manuscript for important intellectual content.

Data Availability

Data used in the Medit-Ageing project are available upon request.

Acknowledgment

Many people helped in implementing this study. The authors would like to thank EUCLID F-CRIN platform for contributions to data management, Rhonda Smith, Charlotte Reid, the sponsor (Pôle de Recherche Clinique at Inserm), Inserm Transfert (Delphine Smagghe), and the participants in the Age-Well and SCD-Well clinical trials.

The Medit-Ageing Research Group includes: Florence Allais, Claire André, Eider Arenaza-Urquijo, Julien Asselineau, Nicholas Ashton, Romain Bachelet, Sebastian Baez Lugo, Thorsten Barnhofer, Martine Batchelor, Axel Beaugonin, Alexandre Bejanin, Viviane Belleoud, Clara Benson, Beatriz Bosch, Maelle Botton, Maria Pilar Casanova, Pierre Champetier, Anne Chocat, Nina Coll-Padros, Rowane Coueron, Sophie Dautricourt, Robin De Flores, Vincent De La Sayette, Pascal Delamillieure, Marion Delarue, Yacila Deza-Araujo, Stéphanie Egret, Hélène Espérou, Francesca Felisatti, Eglantine Ferrand Devouge, Eric Frison, Antoine Garnier-Groussard, Francis Gheysen, Karine Goldet, Julie Gonneaud, Idir Hamdidouche, Marc Heidmann, Yhien Huong Tran, Abdul Hye, Frank Jessen, Agathe Joret Philippe, Pierre Krolak Salmon, Elizabeth Kuhn, Renaud La Joie, Brigitte Landeau, Gwendoline Le Du, Valérie

Lefranc, Maria Leon, Dix Meiberth, Florence Mezenge, Ester Milz, Jose Luis Molinuevo, Inès Moulinet, Hendrik Mueller, Theresa Mueller, Valentin Ourry, Cassandre Palix, Léo Paly, Géraldine Poisnel, Stephano Poletti, Anne Quillard, Alfredo Ramirez, Géraldine Rauchs, Stéphane Rehel, Leslie Reyrolle, Laura Richert, Ana Salinero, Eric Salmon, Raquel Sanchez, Lena Sannemann, Yamna Satgunasingam, Ann-Katrin Schild, Corinne Schimmer, Christine Schwimmer, Siya Sherif, Hilde Steinhauser, Clémence Tomadesso, Edelweiss Touron, Matthieu Vanhoutte, Denis Vivien, Patrik Vuilleumier, Cédrick Wallet, Caitline Ware, Janet Wingrove, and Miranka Wirth.

References

Abdoun, O., Zorn, J., Fucci, E., Perraud, E., Aarts, K., & Lutz, A. (2018). *Brain & mindfulness project manual. OSF.* https://osf.io/dbwch/. Accessed 1 Apr 2021

Baer, R. A., Carmody, J., & Hunsinger, M. (2012). Weekly change in mindfulness and perceived stress in a mindfulness-based stress reduction program. *Journal of Clinical Psychology*, *68*(7), 755–765. https://doi.org/10.1002/jclp.21865

Baer, R. A., Smith, G. T., Hopkins, J., Krietemeyer, J., & Toney, L. (2006). Using self-report assessment methods to explore facets of mindfulness. *Assessment*, *13*(1), 27–45. https://doi.org/10.1177/1073191105283504

Bangen, K. J., Delano-Wood, L., Wierenga, C. E., McCauley, A., Jeste, D. V., Salmon, D. P., & Bondi, M. W. (2010). Associations between stroke risk and cognition in normal aging and Alzheimer's disease with and without depression. *International Journal of Geriatric Psychiatry*, *25*(2), 175–182. https://doi.org/10.1002/gps.2317

Boekel, W., & Hsieh, S. (2018). Cross-sectional white matter microstructure differences in age and trait mindfulness. *PLOS ONE*, *13*(10), e0205718. https://doi.org/10.1371/journal.pone.0205718

Brefczynski-Lewis, J. A., Lutz, A., Schaefer, H. S., Levinson, D. B., & Davidson, R. J. (2007). Neural correlates of attentional expertise in long-term meditation practitioners. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(27), 11483–11488. https://doi.org/10.1073/pnas.0606552104

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*(4), 822–848. https://doi.org/10.1037/0022-3514.84.4.822

Buckley, R. F., Schultz, A. P., Hedden, T., Papp, K. V., Hanseeuw, B. J., Marshall, G., Sepulcre, J., Smith, E. E., Rentz, D. M., Johnson, K. A., Sperling, R. A., & Chhatwal, J. P. (2017).

Functional network integrity presages cognitive decline in preclinical Alzheimer disease. *Neurology*, *89*(1), 29–37. https://doi.org/10.1212/WNL.0000000000004059

Bunce, D., Batterham, P. J., Mackinnon, A. J., & Christensen, H. (2012). Depression, anxiety and cognition in community-dwelling adults aged 70 years and over. *Journal of Psychiatric Research*, *46*(12), 1662–1666. https://doi.org/10.1016/j.jpsychires.2012.08.023

Caprara, G. V., Steca, P., Zelli, A., & Capanna, C. (2005). A new scale for measuring adults' prosocialness. *European Journal of Psychological Assessment*, *21*(2), 77–89. https://doi.org/10.1027/1015-5759.21.2.77

Chang, E. C. (2000). Perfectionism as a predictor of positive and negative psychological outcomes: Examining a mediation model in younger and older adults. *Journal of Counseling Psychology*, *47*(1), 18–26. https://doi.org/10.1037/0022-0167.47.1.18

Chiesa, A., Calati, R., & Serretti, A. (2011). Does mindfulness training improve cognitive abilities? A systematic review of neuropsychological findings. *Clinical Psychology Review*, *31*(3), 449–464. https://doi.org/10.1016/j.cpr.2010.11.003

Craik, F. I. M., & Salthouse, T. A. (Eds.). (2000). *The handbook of aging and cognition* (2nd ed.). Canadian Journal on Aging / La Revue canadienne du vieillissement. https://doi.org/10.1017/s0714980800012332

Creed, A. T., & Funder, D. C. (1998). The two faces of private self-consciousness: Self report, peer-report, and behavioral correlates. *European Journal of Personality*, *12*(6), 411–431. https://doi.org/10.1002/(SICI)1099-0984(199811/12)12:6<411::AID-PER317>3.0.CO;2-C

Dahl, C. J., Lutz, A., & Davidson, R. J. (2015). Reconstructing and deconstructing the self: Cognitive mechanisms in meditation practice. *Trends in Cognitive Sciences*, *19*(9), 515–523. https://doi.org/10.1016/j.tics.2015.07.001

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality and Social Psychology*, *44*(1), 113–126. https://doi.org/10.1037//0022-3514.44.1.113

Dekhtyar, S., Wang, H. X., Scott, K., Goodman, A., Ilona, K., & Herlitz, A. (2015). A life-course study of cognitive reserve in dementia - From childhood to old age. *American Journal of Geriatric Psychiatry*, *23*(9), 885–896. https://doi.org/10.1016/j.jagp.2015.02.002

Demnitz-King, H., Gonneaud, J., Klimecki, O. M., Chocat, A., Collette, F., Dautricourt, S., Jessen, F., Krolak-Salmon, P., Lutz, A., Morse, R. M., Molinuevo, J. L., Poisnel, G., Touron, E., Wirth, M., Walker, Z., Chételat, G., & Marchant, N. L. (2022). Association of self-reflection with cognition and brain health in cognitively unimpaired older adults. *Neurology*, *99*(13), e1422–e1431. https://doi.org/10.1212/wnl.0000000000200951

Donohue, M. C., Sperling, R. A., Salmon, D. P., Rentz, D. M., Raman, R., Thomas, R. G., Weiner, M., & Aisen, P. S. (2014). The preclinical Alzheimer cognitive composite: Measuring amyloid-related decline. *JAMA Neurology*, *71*(8), 961–970. https://doi.org/10.1001/jamaneurol.2014.803

Dotson, V. M. (2014). Unique and interactive effect of anxiety and depressive symptoms on cognitive and brain function in young and older adults. *Journal of Depression and Anxiety*, *S1*(1), 1–10. https://doi.org/10.4172/2167-1044.s1-003

Engert, V., Kok, B. E., Papassotiriou, I., Chrousos, G. P., & Singer, T. (2017). Specific reduction in cortisol stress reactivity after social but not attention-based mental training. *Science Advances*, *3*(10), e1700495. https://doi.org/10.1126/sciadv.1700495

Faul, F., Erdfelder, E., LANG, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods*, *39*(2), 175–191. https://doi.org/https://doi.org/10.3758/BF03193146

Fiocco, A. J., & Mallya, S. (2015). The importance of cultivating mindfulness for cognitive and emotional well-being in late life. *Journal of Evidence-Based Complementary and Alternative Medicine*, *20*(1), 35–40. https://doi.org/10.1177/2156587214553940

Folstein, M. F., Folstein, S. E., & Fanjiang, G. (2001). Mini-Mental State Examination: Clinical guide. In *Psychological Assessment Resources*.

Forman, E. M., Chapman, J. E., Herbert, J. D., Goetter, E. M., Yuen, E. K., & Moitra, E. (2012). Using session-by-session measurement to compare mechanisms of action for acceptance and commitment therapy and cognitive therapy. *Behavior Therapy*, *43*(2), 341–354. https://doi.org/10.1016/j.beth.2011.07.004

Fountain-Zaragoza, S., Londerée, A., Whitmoyer, P., & Prakash, R. S. (2016). Dispositional mindfulness and the wandering mind: Implications for attentional control in older adults. *Consciousness and Cognition*, *44*, 193–204. https://doi.org/10.1016/j.concog.2016.08.003

Fratiglioni, L., & Wang, H.-X. (2007). Brain reserve hypothesis in dementia. *Journal of Alzheimer's Disease : JAD*, *12*(1), 11–22. https://doi.org/10.3233/JAD-2007-12103

Gallant, S. N. (2016). Mindfulness meditation practice and executive functioning: Breaking down the benefit. *Consciousness and Cognition*, *40*, 116–130. https://doi.org/10.1016/j.concog.2016.01.005

Gard, T., Hölzel, B. K., & Lazar, S. W. (2014). The potential effects of meditation on age-related cognitive decline: A systematic review. *Annals of the New York Academy of Sciences*, *1307*(1), 89–103. https://doi.org/10.1111/nyas.12348

Gard, T., Taquet, M., Dixit, R., Hölzel, B. K., de Montjoye, Y. A., Brach, N., Salat, D. H., Dickerson, B. C., Gray, J. R., & Lazar, S. W. (2014). Fluid intelligence and brain functional organization in aging yoga and meditation practitioners. *Frontiers in Aging Neuroscience*, *6*(76), 1–12. https://doi.org/10.3389/fnagi.2014.00076

Godefroy, O. (2008). *Fonctions exécutives et pathologies neurologiques et psychiatriques.*

Evaluation en pratique clinique. (De Boeck Supérieur, ed.).

Groupe de réflexion sur les évaluations cognitives (GRECO). (1994). Échelle d'évaluation de la démence de Mattis. Manuel de passation. Version française consensuelle. Retrieved from http://site-greco.net/download/MATTIS_FeuillesEx.pdf

Hanseeuw, B. J., Betensky, R. A., Jacobs, H. I. L., Schultz, A. P., Sepulcre, J., Becker, J. A., Orozco Cosio, D. M., Farrell, M., Quiroz, Y. T., Mormino, E. C., Buckley, R. F., Papp, K. V., Amariglio, R. A., Dewachter, I., Ivanoiu, A., Huijbers, W., Hedden, T., Marshall, G. A., ... Johnson, K. (2019). Association of amyloid and tau with cognition in preclinical Alzheimer disease: A longitudinal study. *JAMA Neurology*, *76*(8), 915–924. https://doi.org/10.1001/jamaneurol.2019.1424

Innes, K. E., Selfe, T. K., Khalsa, D. S., & Kandati, S. (2017). Meditation and music improve memory and cognitive function in adults with subjective cognitive decline: A pilot randomized controlled trial. *Journal of Alzheimer's Disease*, *56*(3), 899–916. https://doi.org/10.3233/JAD-160867

Jensen, R. A. A., Kirkegaard Thomsen, D., O'Connor, M., & Mehlsen, M. Y. (2020). Age differences in life stories and neuroticism mediate age differences in subjective well-being. *Applied Cognitive Psychology*, *34*(1), 3–15. https://doi.org/10.1002/acp.3580

Kabat-Zinn, J. (2003). Mindfulness-based interventions in context: Past, present, and future. *Clinical Psychology: Science and Practice*, *10*(2), 144–156. https://doi.org/10.1093/clipsy/bpg016

Lu, K., Nicholas, J. M., Collins, J. D., James, S. N., Parker, T. D., Lane, C. A., Keshavan, A., Keuss, S. E., Buchanan, S. M., Murray-Smith, H., Cash, D. M., Sudre, C. H., Malone, I. B., Coath, W., Wong, A., Henley, S. M. D., Crutch, S. J., Fox, N. C., Richards, & M., Schott, J. M. (2019). Cognition at age 70: Life course predictors and associations with brain pathologies. *Neurology*, *93*(23), e2144–e2156.

https://doi.org/10.1212/WNL.0000000000008534

Luchetti, M., Terracciano, A., Stephan, Y., & Sutin, A. R. (2016). Personality and cognitive decline in older adults: Data from a longitudinal sample and meta-analysis. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *71*(4), 591–601. https://doi.org/10.1093/geronb/gbu184

Luders, E., Cherbuin, N., & Gaser, C. (2016). Estimating brain age using high-resolution pattern recognition: Younger brains in long-term meditation practitioners. *NeuroImage*, *134*, 508–513. https://doi.org/10.1016/j.neuroimage.2016.04.007

Lutz, A., Chételat, G., Collette, F., Klimecki, O. M., Marchant, N. L., & Gonneaud, J. (2021). The protective effect of mindfulness and compassion meditation practices on ageing: Hypotheses, models and experimental implementation. *Ageing Research Reviews*, *72*, 101495. https://doi.org/10.1016/j.arr.2021.101495

Lutz, A., Slagter, H. A., Dunne, J. D., & Davidson, R. J. (2008). Attention regulation and monitoring in meditation. *Trends in Cognitive Sciences*, *12*(4), 163–169. https://doi.org/10.1016/j.tics.2008.01.005

Marchant, N. L., Barnhofer, T., Klimecki, O. M., Poisnel, G., Lutz, A., Arenaza-Urquijo, E., Collette, F., Wirth, M., Schild, A. K., Coll-Padrós, N., Reyrolle, L., Horney, D., Krolak-Salmon, P., Molinuevo, J. L., Walker, Z., Maillard, A., Frison, E., Jessen, F., & Chételat, G. (2018). The SCD-Well randomized controlled trial: Effects of a mindfulness-based intervention versus health education on mental health in patients with subjective cognitive decline (SCD). *Alzheimer's and Dementia: Translational Research and Clinical Interventions*, *4*(1), 737–745. https://doi.org/10.1016/j.trci.2018.10.010

Marchant, N. L., Lovland, L. R., Jones, R., Pichet Binette, A., Gonneaud, J., Arenaza-Urquijo, E. M., Chételat, G., & Villeneuve, S. (2020). Repetitive negative thinking is associated with amyloid, tau, and cognitive decline. *Alzheimer's and Dementia*, *16*(7), 1054–1064.

https://doi.org/10.1002/alz.12116

Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2012). The Multidimensional Assessment of Interoceptive Awareness (MAIA). *PLOS ONE*, *7*(11), e48230. https://doi.org/10.1371/journal.pone.0048230

Meng, X., & D'Arcy, C. (2012). Education and dementia in the context of the cognitive reserve hypothesis: A systematic review with meta-analyses and qualitative analyses. *PLOS ONE*, *7*(6), e38268. https://doi.org/10.1371/journal.pone.0038268

Montgomery, S. A., & Asberg, M. (1979). A new depression scale designed to be sensitive to change. *British Journal of Psychiatry*, *134*(4), 382–389. https://doi.org/10.1192/bjp.134.4.382

Mormino, E. C., Papp, K. V., Rentz, D. M., Donohue, M. C., Amariglio, R., Quiroz, Y. T., Chhatwal, J., Marshall, G. A., Donovan, N., Jackson, J., Gatchel, J. R., Hanseeuw, B. J., Schultz, A. P., Aisen, P. S., Johnson, K. A., & Sperling, R. A. (2017). Early and late change on the preclinical Alzheimer's cognitive composite in clinically normal older individuals with elevated amyloid β. *Alzheimer's and Dementia*, *13*(9), 1004–1012. https://doi.org/10.1016/j.jalz.2017.01.018

Neupert, S. D., Mroczek, D. K., & Spiro, A. (2008). Neuroticism moderates the daily relation between stressors and memory failures. *Psychology and Aging*, *23*(2), 287–296. https://doi.org/10.1037/0882-7974.23.2.287

Newberg, A. B., Wintering, N., Khalsa, D. S., Roggenkamp, H., & Waldman, M. R. (2010). Meditation effects on cognitive function and cerebral blood flow in subjects with memory loss: A preliminary study. *Journal of Alzheimer's Disease*, *20*(2), 517–526. https://doi.org/10.3233/JAD-2010-1391

Olaya, B., Bobak, M., Haro, J. M., & Demakakos, P. (2017). Trajectories of verbal episodic memory in middle-aged and older adults: Evidence from the English longitudinal study of ageing. *Journal of the American Geriatrics Society*, *65*(6), 1274–1281. https://doi.org/10.1111/jgs.14789

Ossenkoppele, R., Zwan, M. D., Tolboom, N., Van Assema, D. M. E., Adriaanse, S. F., Kloet, R. W., Boellaard, R., Windhorst, A. D., Barkhof, F., Lammertsma, A. A., Scheltens, P., Van Der Flier, W. M., & Van Berckel, B. N. M. (2012). Amyloid burden and metabolic function in early-onset Alzheimer's disease: Parietal lobe involvement. *Brain*, *135*(7), 2115–2125. https://doi.org/10.1093/brain/aws113

Papp, K. V., Rentz, D. M., Orlovsky, I., Sperling, R. A., & Mormino, E. C. (2017). Optimizing the preclinical Alzheimer's cognitive composite with semantic processing: The PACC5. *Alzheimer's and Dementia: Translational Research and Clinical Interventions*, *3*(4), 668–677. https://doi.org/10.1016/j.trci.2017.10.004

Park, D. C., & Reuter-Lorenz, P. (2009). The adaptive brain: Aging and neurocognitive scaffolding. *Annual Review of Psychology*, *60*, 173–196. https://doi.org/10.1146/annurev.psych.59.103006.093656

Plaisant, O., Courtois, R., Réveillère, C., Mendelsohn, G. A., & John, O. P. (2010). Validation par analyse factorielle du Big Five Inventory français (BFI-Fr). Analyse convergente avec le NEO-PI-R. *Annales Medico-Psychologiques*, *168*(2), 97–106. https://doi.org/10.1016/j.amp.2009.09.003

Podsakoff, P. M., MacKenzie, S. B., & Podsakoff, N. P. (2012). Sources of method bias in social science research and recommendations on how to control it. *Annual Review of Psychology*, *63*, 539–569. https://doi.org/10.1146/annurev-psych-120710-100452

Poisnel, G., Arenaza-Urquijo, E., Collette, F., Klimecki, O. M., Marchant, N. L., Wirth, M., de La Sayette, V., Rauchs, G., Salmon, E., A., Vuilleumier, P., Frison, E., Maillard, A., Vivien, D., Lutz, A., & Chételat, G. (2018). The Age-Well randomized controlled trial of the Medit-Ageing European project: Effect of meditation or foreign language training on brain and mental health in older adults. *Alzheimer's and Dementia: Translational Research and Clinical Interventions*, *4*, 714–723. https://doi.org/10.1016/j.trci.2018.10.011

Poitrenaud, J., Deweer, B., Kalafat, M., & Van der Linden, M. (2007). Adaptation en langue française du California Verbal Learning Test. (Les Éditions du Centre de Psychologie Appliquée, ed.).

Prakash, R., Rastogi, P., Dubey, I., Abhishek, P., Chaudhury, S., & Small, B. J. (2012). Long-term concentrative meditation and cognitive performance among older adults. *Aging, Neuropsychology, and Cognition*, *19*(4), 479–494. https://doi.org/10.1080/13825585.2011.630932

Prakash, R. S., Hussain, M. A., & Schirda, B. (2015). The role of emotion regulation and cognitive control in the association between mindfulness disposition and stress. *Psychology and Aging*, *30*(1), 160–171. https://doi.org/10.1037/a0038544

Qiu, C., & Fratiglioni, L. (2018). Aging without dementia is achievable: Current evidence from epidemiological research. *Journal of Alzheimer's Disease*, *62*(3), 933–942. https://doi.org/10.3233/JAD-171037

R Core Team. (2020). R: A language and environment for statistical computing. *R Foundation for Statistical Computing*. Retrieved from http://www.r-project.org/

Raes, A. K., Bruyneel, L., Loeys, T., Moerkerke, B., & De Raedt, R. (2015). Mindful attention and awareness mediate the association between age and negative affect. *Journals of Gerontology - Series B Psychological Sciences and Social Sciences*, *70*(2), 179–188. https://doi.org/10.1093/geronb/gbt074

Raes, F., Pommier, E., Neff, K. D., & Van Gucht, D. (2011). Construction and factorial validation of a short form of the Self-Compassion Scale. *Clinical Psychology and Psychotherapy*, *18*(3), 250–255. https://doi.org/10.1002/cpp.702

Reuter-Lorenz, P. A., & Park, D. C. (2014). How does it STAC up? Revisiting the Scaffolding Theory of Aging and Cognition. *Neuropsychology Review*, *24*(3), 355–370. https://doi.org/10.1007/s11065-014-9270-9

Rönnlund, M., Nyberg, L., Bäckman, L., & Nilsson, L. G. (2005). Stability, growth, and decline in adult life span development of declarative memory: Cross-sectional and longitudinal data from a population-based study. *Psychology and Aging*, *20*(1), 3–18. https://doi.org/10.1037/0882-7974.20.1.3

SAS Institute Incorporation. (2013). Base SAS®9.4 Procedures Guide. In *Statistical Procedures*.

Schlosser, M., Barnhofer, T., Requier, F., Deza-Araujo, Y. I., Abdoun, O., Marchant, N. L., Chételat, G., Collette, F., Klimecki, O. M., Lutz, A., & Lutz, A. (2022). Measuring Psychological Mechanisms in Meditation Practice: Using a Phenomenologically Grounded Classification System to Develop Theory-Based Composite Scores. *Mindfulness*, *13*(3), 600–614. https://doi.org/10.1007/s12671-021-01816-0

Schlosser, M., Jones, R., Demnitz-King, H., & Marchant, N. L. (2020). Meditation experience is associated with lower levels of repetitive negative thinking: The key role of self-compassion. *Current Psychology*, *41*, 3144–3155. https://doi.org/10.1007/s12144-020-00839-5

Segal, Z. V., Anderson, A. K., Gulamani, T., Williams, L. A. D., Desormeau, P., Ferguson, A., Walsh, K., & Farb, N. A. S. (2019). Practice of therapy acquired regulatory skills and depressive relapse/ recurrence prophylaxis following cognitive therapy or mindfulness based cognitive therapy. *Journal of Consulting and Clinical Psychology*, *87*(2), 161–170. https://doi.org/10.1037/ccp0000351.supp

Sperduti, M., Makowski, D., & Piolino, P. (2016). The protective role of long-term meditation on the decline of the executive component of attention in aging: A preliminary cross-sectional study. *Aging, Neuropsychology, and Cognition*, *23*(6), 691–702. https://doi.org/10.1080/13825585.2016.1159652

Spielberger, C. D., Gorsuch, R. L., & Lushene, R. E. (1970). *STAI manual for the State-Trait Anxiety Inventory. Self-evaluation questionnaire*.

Strikwerda-Brown, C., Ozlen, H., Pichet Binette, A., Chapleau, M., Marchant, N. L., Breitner, J. C. S., & Villeneuve, S. (2022). Trait mindfulness is associated with less amyloid, tau, and cognitive decline in individuals at risk for Alzheimer's disease. *Biological Psychiatry Global Open Science*, *3*(1), 130-138. https://doi.org/10.1016/j.bpsgos.2022.01.001

Tang, Y. Y., Hölzel, B. K., & Posner, M. I. (2015). The neuroscience of mindfulness meditation. *Nature Reviews Neuroscience*, *16*(4), 213–225. https://doi.org/10.1038/nrn3916

Terracciano, A., Stephan, Y., Luchetti, M., Albanese, E., & Sutin, A. R. (2017). Personality traits and risk of cognitive impairment and dementia. *Journal of Psychiatric Research*, *89*, 22–27. https://doi.org/10.1016/j.jpsychires.2017.01.011

Then, F. S., Luck, T., Luppa, M., Thinschmidt, M., Deckert, S., Nieuwenhuijsen, K., … Riedel-Heller, S. G. (2014). Systematic review of the effect of the psychosocial working environment on cognition and dementia. *Occupational and Environmental Medicine*, *71*(5), 358–365. https://doi.org/10.1136/oemed-2013-101760

Trapnell, P. D., & Campbell, J. D. (1999). Private self-consciousness and the five-factor model of personality: Distinguishing rumination from reflection. *Journal of Personality and Social Psychology*, *76*(2), 284–304. https://doi.org/10.1037/0022-3514.76.2.284

United Nation. (2019). World Population Ageing 2019: Highlights (ST/ESA/SER.A/430). Official. In *Economic and Social Affairs, Population Division*.

Valk, S. L., Bernhardt, B. C., Trautwein, F. M., Böckler, A., Kanske, P., Guizard, N., Collins, D. L., & Singer, T. (2017). Structural plasticity of the social brain: Differential change after socio-affective and cognitive mental training. *Science Advances*, *3*(10), 1–12.

https://doi.org/10.1126/sciadv.1700489

Wallace, B. A., & Shapiro, S. L. (2006). Mental balance and well-being: Building bridges between Buddhism and Western psychology. *American Psychologist*, *61*(7), 690–701. https://doi.org/10.1037/0003-066X.61.7.690

Wang, H.-X., Xu, W., & Pei, J. J. (2012). Leisure activities, cognition and dementia. *Biochimica et Biophysica Acta - Molecular Basis of Disease*, *1822*(3), 482–491. https://doi.org/10.1016/j.bbadis.2011.09.002

Wechsler, D, (2008) Pearson, Wechler Adult Intelligence Scale (WAIS) IV. In *Pearson Education.*

Whitfield, T., Barnhofer, T., Acabchuk, R., Cohen, A., Lee, M., Schlosser, M., Arenaza-Urquijo, E. M., Böttcher, A., Britton, W., Coll-Padros, N., Collette, F., Chételat, G., Dautricourt, S., Demnitz-King, H., Dumais, T., Klimecki, O., Meiberth, D., Moulinet, I., … Marchant, N. L. (2021). The effect of mindfulness-based programs on cognitive function in adults: A systematic review and meta-analysis. *Neuropsychology Review*, *32*, 677–702. https://doi.org/10.1007/s11065-021-09519-y

Wolkin, J. R. (2015). Cultivating multiple aspects of attention through mindfulness meditation accounts for psychological well-being through decreased rumination. *Psychology Research and Behavior Management*, *8*, 171–180. https://doi.org/10.2147/PRBM.S31458

Yasavage, J. A., & Sheikh, J. I. (1986). 9/Geriatric Depression Scale (GDS) Recent Evidence and Development of a Shorter Version. *Clinical Gerontologist*, *5*(1–2), 165–173.

Zorn, J., Abdoun, O., Bouet, R., & Lutz, A. (2020). Mindfulness meditation is related to sensory-affective uncoupling of pain in trained novice and expert practitioners. *European Journal of Pain*, *24*(7), 1301–1313. https://doi.org/10.1002/ejp.1576

Table 1. Descriptive data of the demographics of 134 healthy old participants

Demographic information	**Mean (*n*=134)**
Age *(years, mean ± SD)*	69.3 ± 3.8
Education *(number of years, mean ± SD)*	13.1 ± 3.1
Gender *(women, %)*	61.2
MMSE *(raw score, mean ± SD)*	29.0 ± 1.0

Note. SD: Standard Deviation MMSE: Mini Mental State Examination.

Table 2. Correlations between demographic information, affective state, personality and meditation capacities

	Education (years)	***Age (years)***	***STAI-B***	***GDS***	***Neuroticism***
Meditation capacities					
Attentional	*r = .12* *p = .16*	*r = -.04* *p = .61*	***r = -.17*** ***p* < .05**	*r = .004* *p = .96*	*r = -.07* *p = .40*
Deconstructive	*r = .14* *p = .10*	*r = .10* *p = .26*	***r = -.61*** ***p* < .001**	***r = -.18*** ***p* < .05**	***r = -.69*** ***p* < .001**
Constructive	*r = .05* *p = .58*	*r = .10* *p = .26*	*r = .11* *p = .20*	*r = -.02* *p = .79*	*r = .13* *p = .14*

Note. n=134, GDS: Geriatric Depression Scale, STAI: State-Trait Anxiety Inventory.

Table 3. Statistical outcomes of the regression analyses seeking for the association between cognitive performance and meditation capacities.

Capacities	**Estimate ± SE**	**F value (df)**	**P**
(A) Cognitive composite score of attention			
Attentional	-0.02 ± 0.09	0.04 (1,130)	.85
Deconstructive	0.07 ± 0.09	0.56 (1,130)	.45
Constructive	-0.07 ± 0.09	0.57 (1,130)	.45
(B) Cognitive composite score of executive function			
Attentional	0.07 ± 0.09	0.54 (1,130)	.46
Deconstructive	0.12 ± 0.09	1.97 (1,130)	.16
Constructive	0.04 ± 0.09	0.27 (1,130)	.61
(C) Cognitive composite score of episodic memory			
Attentional	-0.08 ± 0.09	0.77 (1,130)	.38
Deconstructive	0.12 ± 0.09	1.98 (1,130)	.16
Constructive	0.15 ± 0.09	2.98 (1,130)	.09
(D) PACC5 score			
Attentional	-0.12 ± 0.09	1.81 (1,130)	.18
Deconstructive	**0.18 ± 0.09**	**4.34 (1,130)**	**.04 (R_{sp}^2=.03)**
Constructive	0.11 ± 0.09	1.61 (1,130)	.21

Note. SE: Standard Error, df: degrees of freedom, R_{sp}^2: semi-partial R^2, *n*=134.

Table 4. Mediation analysis: meditative capacities and affective data as mediators on PACC5 performance.

Parameters	Estimate ± SE	Z	P	CI
Attentional ~~ Deconstructive	0.20 ± 0.09	2.30	**.02**	[0.03:0.37]
PACC5 ~ Attentional	-0.14 ± 0.08	-1.70	.09	[-0.31:0.02]
PACC5 ~ Constructive	0.10 ± 0.08	1.16	.25	[-0.07:0.26]
PACC5 ~ Deconstructive	0.30 ± 0.12	2.49	**.01**	[0.06:0.53]
GDS ~~ STAI-B	3.62 ± 0.87	4.16	**<.001**	[1.91:5.33]
STAI-B ~~ Neuroticism	1.52 ± 0.29	5.28	**<.001**	[0.96:2.08]
Neuroticism ~~ GDS	0.34 ± 0.08	4.07	**<.001**	[0.18:0.51]
GDS ~ Deconstructive	-0.32 ± 0.15	-2.14	**.03**	[-0.60:-0.03]
PACC5 ~ GDS	0.01 ± 0.05	0.11	.91	[-0.10:0.11]
STAI-B ~ Deconstructive	-4.27 ± 0.48	-8.89	**<.001**	[-5.21:-3.33]
PACC5 ~ STAI-B	-0.02 ± 0.02	-1.10	.27	[-0.05:0.02]
Neuroticism ~ Deconstructive	-0.51 ± 0.05	-10.93	**<.001**	[-0.60:-0.42]
PACC5 ~ Neuroticism	0.38 ± 0.18	2.09	**.04**	[0.02:0.74]
Indirect effect with STAI-B	0.08 ± 0.08	1.09	.28	[-0.07:0.23]
Total effect with STAI-B	0.10 ± 0.11	0.92	.36	[-0.12:0.33]
Indirect effect with GDS	-0.002 ± 0.02	-0.11	.91	[-0.04:0.03]
Total effect with GDS	0.30 ± 0.12	2.39	**.02**	[0.05:0.54]
Indirect effect with neuroticism	-0.19 ± 0.09	-2.05	**.04**	[-0.38:-0.01]
Total effect with neuroticism	0.10 ± 0.11	0.92	.36	[-0.12:0.33]

Note. SE: Standard Error, STAI: State Trait Anxiety Inventory, CI: Confidence Interval, *n*=134, ~~ association/correlation, ~ regression, indirect effect: mediating effect, total effect: direct and indirect effect of one mediation model.

Figure 1. Flow diagram of the inclusion process

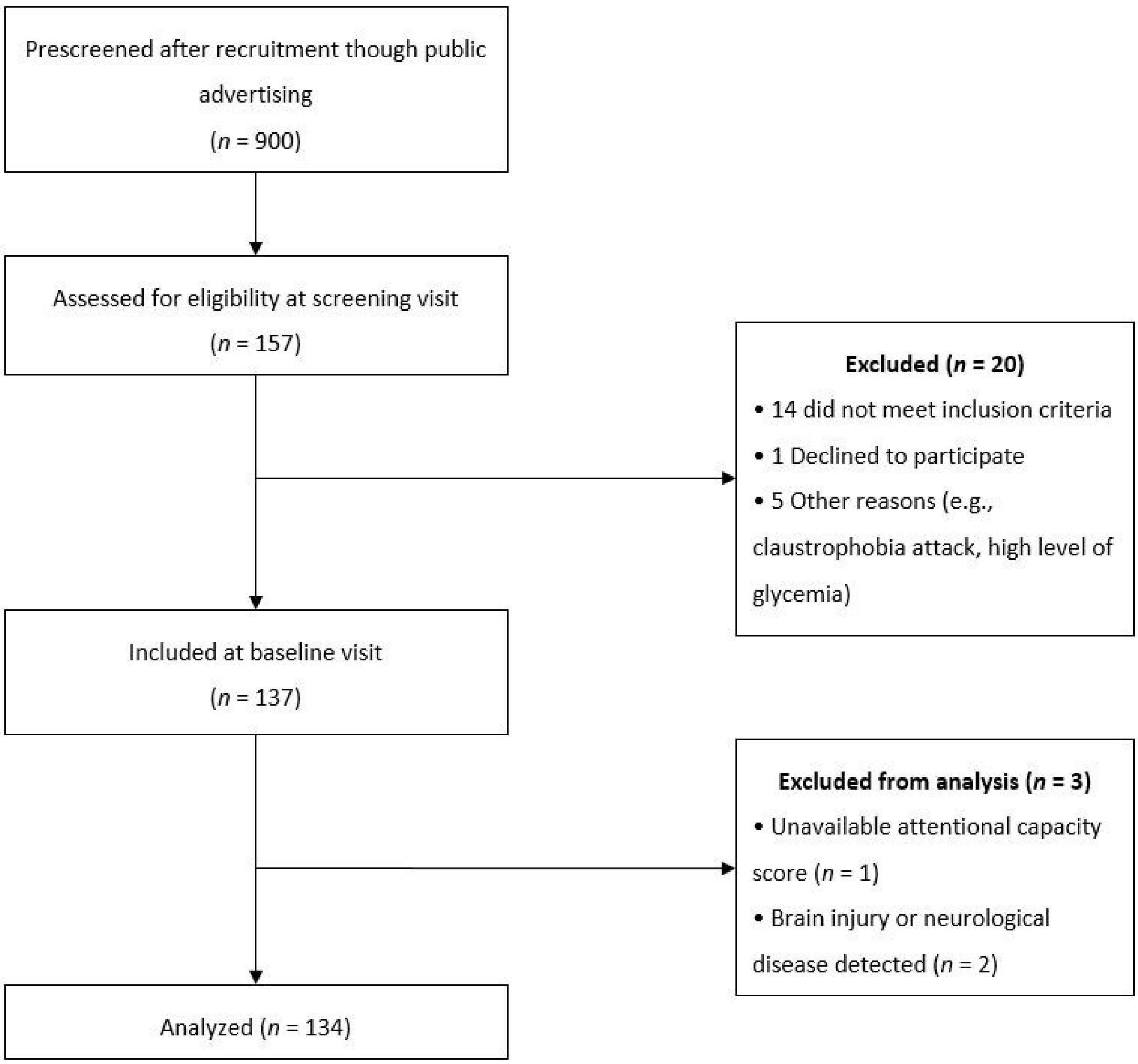
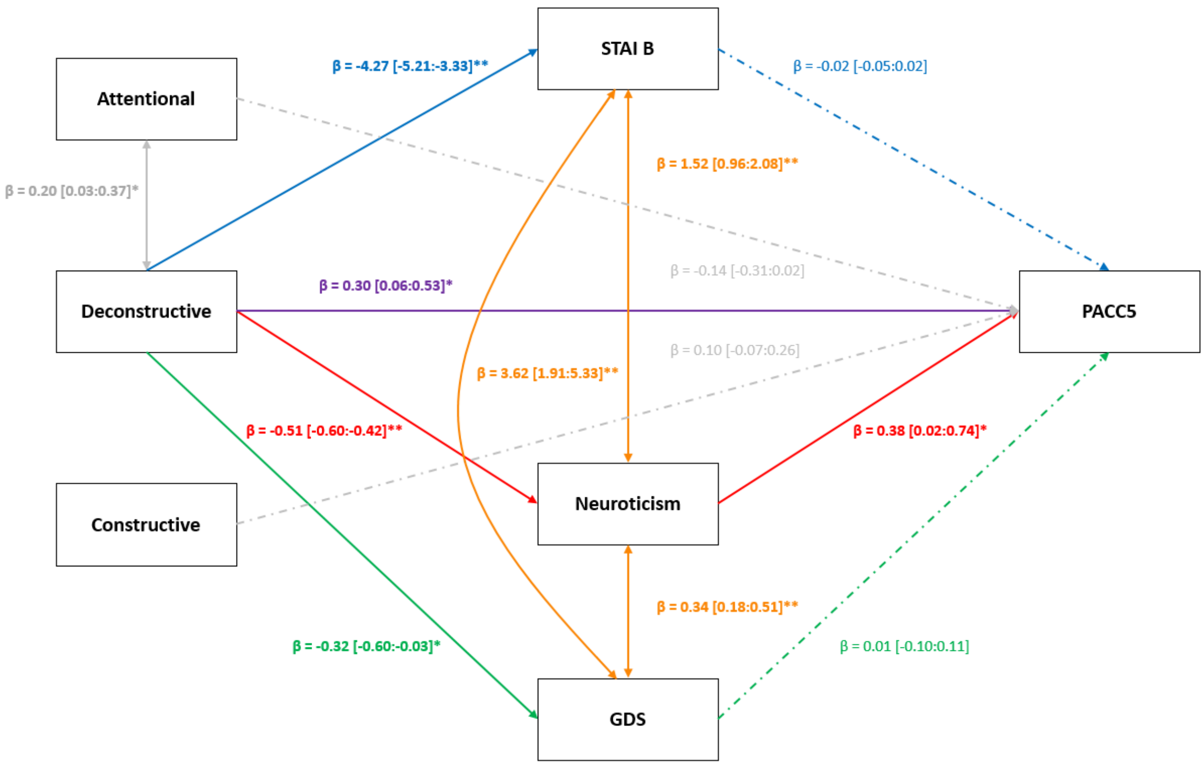


Figure 2. Mediation analysis: relationship between deconstructive capacity and global cognition (PACC5) with STAI-B, GDS and neuroticism as mediators



Note. * p<.05, ** p<.001. Bidirectional arrows represent associations between variables, and unidirectional arrows the direct effects. Statistical values for indirect and total effects are presented in Table 4.