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Mindfulness induction and cognition: A systematic review and meta-analysis

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ABSTRACT

Mindfulness meditation might improve a variety of cognitive processes, but the available evidence remains fragmented. This preregistered meta-analysis (PROSPERO-CRD42018100320) aimed to provide insight into this hypothesis by assessing the effects of brief mindful attention induction on cognition. Articles were retrieved from Pubmed, PsycInfo and Web of Science up until August 1, 2018. A total of 34 studies were included. The outcomes were categorized into four cognitive domains: attentional functioning, memory, executive functioning and higher-order function. A small effect was found across all cognitive domains (*Hedges' g* = 0.18, *95% IC* = 0.07–0.29). Separated analyses for each cognitive domain revealed an effect only in higher-order cognitive functions (k = 10, *Hedges' g* = 0.35, *95% IC* = 0.20–0.50). Results suggest that mindfulness induction improves cognitive performance in tasks involving complex higher-order functions. There was no evidence of publication bias, but studies generally presented many methodological flaws.

1. Introduction

1.1. Background

Mindfulness is generally described as a state of non-judgmental attention to present experiences and is typically cultivated by meditation practices (Kabat-Zinn, 2003). It was initially considered a specific mental training embedded in a set of principles and disciplines intended to reduce human suffering (Bodhi, 2011). Today, mindfulness meditation has been integrated into effective modern clinical programs (Khoury et al., 2013) such as Mindfulness-Based Stress Reduction (MBSR; Santorelli, 2014) and Mindfulness-Based Cognitive Therapy (MBCT; Segal et al., 2013).

Although there are many different conceptualizations of mindfulness meditation (Van Dam et al., 2018), it is generally accepted that it is a mental practice relying upon multiple cognitive processes. Tang et al. (2015) define attention and self-awareness as central features of mindfulness meditation; Lutz et al. (2008) highlighted the importance of attentional processes in mindfulness by putting forward a conceptualization of mindfulness founded on the orientation of attention during meditation; Vago and Silbersweig (2012) stressed the importance of executive functions, working memory and episodic memory during mindfulness meditation.

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These models of mindfulness also suggest that the practice of meditation might lead to long-term cognitive enhancements. Structural and functional changes in the alerting, orienting, and executive attentional neural networks of the brain were reported in response to the practice of mindfulness meditation (Tang et al., 2015; Vago & Silbersweig, 2012). Correspondingly, attentional capacities, such as sustained, selective and divided attention, are thought to be enhanced by mindfulness practice (Hölzel et al., 2011; Lutz et al., 2008; Tang et al., 2015 Vago & Silbersweig, 2012).

1.2. Research findings and challenges in mindfulness research

A considerable limitation of these models is that the underlying evidence is generally based on studies with poor methodological quality or methodology that precludes causality inference (Tang et al., 2015). For example, correlational studies (e.g., Moore & Malinowski, 2009; Rice & Liu, 2017), case-control studies with expert meditators (e.g., Davidson, Goleman, & Schwartz, 1976; Hodgins & Adair, 2010; Moore & Malinowski, 2009) or longitudinal studies without control groups (e.g., Kozasa et al., 2015; Wong, Teng, Chee, Doshi, & Lim, 2018) typically report positive effects of mindfulness on cognitive functions. However, this is not necessarily the case in randomized control trials with robust methodology including adequate control comparison, blinding, and preregistration (e.g., MacCoon, MacLean, Davidson, Saron, & Lutz, 2014).

In line with this, a review investigating the effects of mindfulness on cognition concluded that there was mixed support for a positive effect of mindfulness meditation on attention and executive functions (Chiesa, Calati & Serretti, 2011). The review also highlighted many methodological flaws among the 15 longitudinal and eight cross-sectional studies it included, such as lack of active control group, lack of proper randomization and lack of blinding procedures. Another systematic review found evidence of a positive effect of mindfulness-based interventions for attentional deficits observed in the attention-deficit hyperactivity disorder (Lee et al., 2017). However, these findings were based on a few studies with small sample sizes and thus warrant cautious interpretation.

Another limitation of mindfulness research is the heterogeneity of mindfulness practices (Van Dam et al., 2018). Prominent authors in the field warned against an oversimplification of the broad inventory of mindfulness practices (Lutz et al., 2015; Kabat-Zinn, 2017). This suggests that each practice must be considered in its specificity, and thus further weakens the possible interpretation of existing evidence regarding a general benefit of mindfulness training on cognition.

In sum, there is evidence suggesting that mindfulness meditation might improve cognition, but inconsistencies in results, methodology and conceptualization preclude any definite conclusion.

1.3. Mindfulness induction, a promising design

Mindfulness induction is a single and brief session of mindfulness training, designed to induce a temporary state of mindfulness (Creswell, 2017). This design is a promising research avenue that diminishes the methodological and conceptual flaws that have been identified in mindfulness research. The majority of mindfulness intervention research studies a mindfulness training program that encompasses many practices and potential therapeutic elements. In the case of the mindfulness induction design, specific mindfulness practices can be isolated and investigated separately. Moreover, because mindfulness induction can be entirely conducted in laboratory settings, it is far easier for researchers to implement robust methodological protocols such as control groups, standardized instructions, appropriate blinding procedures and manipulation checks. Consequently, the momentary cognitive impact of specific mindfulness instructions can be evaluated with high confidence.

Of particular interest in the research on cognition is the Mindful Attention Induction (MAI), in which an attentional form of meditation (Dahl et al., 2015) is practiced. According to Lutz et al. (2008), attentional meditation can be distinguished on a continuum of attention orientation. On one end of the continuum is the Focused Attention (FA) meditation, in which the meditator attempts to be aware of a specific perceptual object (such as the sensation of breathing). The meditator carefully monitors the changing perception associated with the object and must reorient their attention to it whenever their attention wanders. At the other end is the Open Monitoring (OM) meditation, in which the meditator tries to be aware of each perception and mental process as they unfold. Both forms of meditation are the foundation of the multiple mindfulness exercises encompassed in mindfulness-based intervention programs (Crane & Kuyken, 2018; Santorelli, 2014).

Despite the burgeoning popularity of MAIs (see Schumer et al., 2018 for a review), inconsistent findings yet again prevent any definite conclusions, at least in regards to their effects on cognitive functioning. For example, some studies found a positive effect of MAIs on long-term memory (Baranski & Was, 2017; Calvillo, Flores, & Gonzales, 2018), while others found the exact opposite (Wilson, Mickes, Stolarz-Fantino, Evrard, & Fantino, 2015). Summarizing and quantifying the evidence regarding the effects of MAIs on cognitive functioning is, therefore, an important step toward a better comprehension of an essential component of mindfulness-based interventions.

1.4. Present study

The present study aimed to review the effects of MAIs on various cognitive outcomes in healthy populations and to conduct a meta-analysis of the reported effect sizes. We aimed to (1) include various cognitive outcomes, (2) use a rigorous tool to analyze potential bias in individual studies (Higgins et al., 2011) and (3) compute effect sizes of the effects of MAIs across and within each type of intervention and each domain of cognitive outcome.

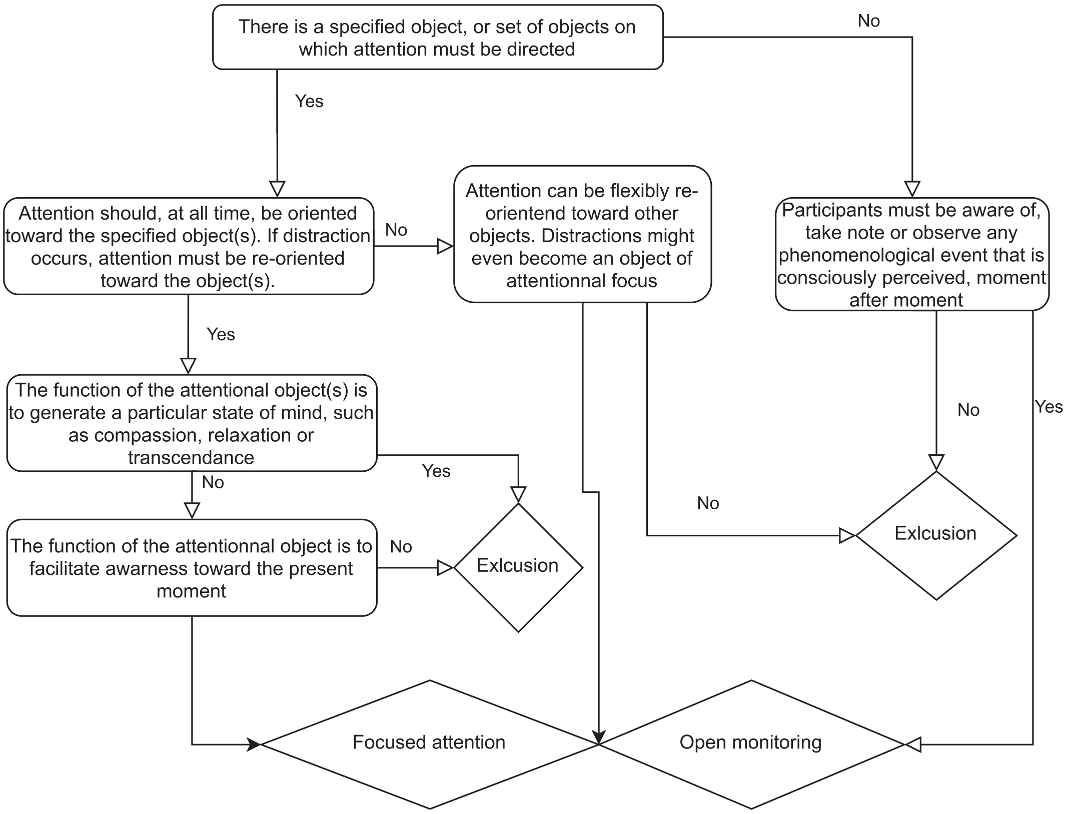

Fig. 1. Decision tree regarding the meditation type. Only MAIs that could be defined on the FA-OM continuum were included. Note that MAIs that included both FA and OM element were considered as a Mixed type of induction.

2. Methods

2.1. Protocol and registration

This review was conducted according to the PRISMA standards (see Annexe C). The protocol was preregistered on the PROSPERO database (ID = CRD42018100320) on June 12th, 2018. The study deviated from the original protocol in two ways. First, the pediatric population was excluded from the analyses because of the dynamic aspect of cognitive development and the limited number of relevant studies. Second, to complement the expertise of the research team regarding cognitive functioning, another author (EC), joined the project.

2.2. Eligibility criteria

Studies were considered in this review if:

1. They included a MAI, that is, a mindfulness induction specified as either FA, OM or Mixed (see Fig. 1);
2. They tested the effects of a MAI on cognitive function in a healthy adult population,
3. Participants were aged between 18 and 65 years old. The upper-bound was selected because of the changes in cognitive processes observed even in healthy elderly population (see Glisky, 2007; Harada et al., 2013);
4. They used a within-subject, between-subject, or mixed design (within-between).

Studies were excluded if they:

1. Included other forms of mindfulness training before or after the mindfulness induction;
2. Administered a short meditation training that fell outside of the FA to OM continuum, before or after the induction (Dahl et al., 2015; Lutz et al., 2008), as explained in Fig. 1;
3. Targeted populations with previous experience with mindfulness meditation (e.g., studies that compared experts to novice meditators);
4. Did not measure or report an objective cognitive performance measure;

5. Did not assess cognitive performance during or immediately after the mindfulness induction;
6. Did not compare the MAI to an active control intervention.

Finally, because of the experimental nature of the reviewed studies, it was sometimes possible to identify multiple studies (i.e., independent experimentations or independent populations being tested) in a single article.

2.3. Information source

Studies were identified by searching PsycINFO, PubMed and Web of Science from the first available date up to August 1, 2018. These databases all index neuropsychology and psychology journals but do not significantly intersect. The search was limited to articles with an English title and abstract. The search terms were: (“Mindful” OR “Meditation”) AND (“brief” OR “Short” OR “Induction” OR “Suggestion” OR “One-time”).

2.4. Study selection

Eligibility assessment was performed independently by the first and second authors. Disagreements between reviewers on eligibility or any of the extracted information were resolved through discussions. If additional information was necessary, the authors of the articles were contacted.

The initial level of agreement between reviewers was substantial (k = 0.80). Note that a kappa of 0 indicates agreement that would be expected by chance, while 1 represents a perfect agreement (McHugh, 2012). The disagreements between authors only concerned the cognitive outcome criteria, as some studies included cognitive measures for which it was unclear what constituted an improvement, or included measures that were coupled with motivational, emotional, or motor-related variables. After discussion, a conservative consensus was reached to exclude such studies despite their obvious cognitive component. For example, a study on goal setting was excluded. While goal setting requires executive planning, the outcome measure in this study was the type of goal chosen by participants, which significantly relies on motivational processes. The authors, therefore, agreed that this outcome was not a reliable indicator of cognitive improvement.

2.5. Data collection process

Data were extracted independently by the first and second authors using a standardized form, and when possible, data were extracted from graphs using WebPlotDigitizer (https://automeris.io/WebPlotDigitizer/). Standardized mean differences of dichotomous data were extracted with the frequency tables using the Practical Meta-Analysis Effect Size Calculator of the Campbell Collaboration (Lipsey & Wilson, 2001). When data were missing, the corresponding author of the studies was contacted by email. To extract data from articles, the copy/paste function was systematically used to minimize any human error in data reproduction.

2.6. Data items

Data were extracted from each included study based on the characteristics of (1) the intervention (e.g., length, FA, OM or mixed type and method of delivery) and of the control intervention; (2) the participants (e.g., sample size, mean age and percentage of females), (3) the experimental design (e.g., randomization and blinding procedure) and (4) the number of participants, means and standard deviations. If means or standard deviations were not reported, we extracted any other statistical data from which a standardized effect size could be computed (e.g., *SE*, *CI*, *F*, *d, p*).

2.7. Risk of bias within studies

Two reviewers (LNG and RR) independently assessed the risk of bias in the studies using the Cochrane assessment of bias tool (Higgins & Green, 2011). This tool assesses potential threats to the internal validity of randomized controlled trials across six domains of bias: selection bias, performance bias, detection bias, attrition bias, reporting bias, and other biases. For each domain, a level of risk is identified (Low risk, High Risk or Unclear). The methodological quality of a study is based on overall risk of bias and is assessed as *poor*, *fair*, or *good*. Note that the “Other Bias” section of the tool was used primarily to assess if there were any potential threats to the validity of the mindfulness induction (e.g., unclear mindfulness instructions).

2.8. Summary measures

The main summary measures were mean differences in cognitive performance variables between (1) induction intervention and control intervention (within-subject design), (2) control and mindfulness induction groups (between-subject design) or (3) pre-post measure, with a control group (between-within subject design).

2.9. Summary results and synthesis of results

As studies differed in terms of outcome measures, target population and style of training, the outcomes were pooled using a random-effects model (Borenstein, Hedges, Higgins, & Rothstein, 2009). Hedges' g (further referred to as g), its 95% confidence interval (further referred to as CI), and the p values were computed for all primary (cognitive performance) and secondary (mindfulness) outcomes. The heterogeneity among studies in each group was assessed using I^2 and the χ^2 statistics. All statistics were computed using Comprehensive Meta-Analysis-CMA (3.0) by BioStats Inc. The primary feature of CMA is to compute effect sizes from different measures, under both random and fixed models, by using the z distribution. CMA is a widely used software to conduct meta-analyses, and it produces results comparable to other frequently used programs such as STATA, MIX and RevMan (Bax et al., 2007). Forest plots were plotted on the results exported from CMA using Rstudio (1.2.5033), with the *Meta* package (Harrer et al., 2019).

2.10. Risk of bias across studies

The publication bias was assessed using the fail-safe N and the funnel plot. The fail-safe N specifies the number of studies with no effects that would be needed to nullify the obtained results (considering a two-tailed p-value > 0.05). The funnel plot was used as an additional visual aid for detecting publication bias.

2.11. Additional analysis

Subgroup analyses were conducted for FA, OM and Mixed (including both FA and OM elements) type of induction, as well as for the different cognitive outcome domains. If the cognitive domain was not clearly stated in the study, the tasks were analyzed to identify the cognitive processes in play. Meta-regression analyses were also conducted with age, gender (% of female participants), induction duration and study quality as covariables. Study quality was quantified with the results of the risk of individual study bias analysis, where each "Low risk" domain was given a value of 1, each "Unclear risk" domain a value of 0 and each "High risk" domain a value of −1.

3. Results

3.1. Study selection

Thirty-four independent experiments totalizing 3524 participants were examined in the present meta-analysis. See the study selection process in Fig. 2.

3.2. Study characteristics

Table 1 presents the cognitive domains investigated in the included studies. Detailed characteristics of each study are also presented in the Supplementary Material (Appendix A).

3.3. Risk of bias within studies

Overall, most of the included studies were of poor methodological quality (Poor quality: 32 studies; Fair quality: 2 studies; Good quality: 0 study). Fig. 3 shows the frequency of each level of risk for each domain of bias. Detailed data of the risk of bias analysis are presented in Supplementary Material (Appendix B).

3.4. Synthesis of results

3.4.1. Effect of MAI on overall cognition

Pooling data from all included studies ($k = 34$) revealed a small effect of mindfulness on cognition ($n = 3524$, $g = 0.18$, 95% $CI = 0.07–0.29$, $p = .003$). Additionally, heterogeneity was moderate, $Tau^2 = 0.074$ and $I^2 = 51.6\%$. The forest plot is presented in Fig. 4.

3.4.2. Effect of MAI on overall cognition by type of induction

Separate analyses were conducted on each induction type (see Figs. 5 and 6). Mixed induction produced a significant but small effect on overall cognition ($k = 7$, $n = 1019$, $g = 0.32$, $CI = 0.08–0.56$, $p = .012$, $Tau^2 = 0.043$, $I^2 = 41.8\%$), but no significant effect was found for FA ($k = 25$, $n = 2299$, $g = 0.11$, $CI = -0.02$ to 0.25, $p = .099$, $Tau^2 = 0.098$, $I^2 = 86.1\%$). There was not a sufficient number of OM studies to conduct the analysis.

3.4.3. Effect of MAI by cognitive domain

The classification for each cognitive domain and subdomain is presented in Table 2. Only the higher-order functions showed a significant effect. Hedges' g, 95% CI, p-value and heterogeneity statistics for each cognitive domain are presented in Table 2. Forest plots for each analysis are presented in Figs. 7–11.

3.4.4. Effect of MAI on mindfulness

Overall, 14 experiments had a post or pre/post measures of state-mindfulness. There was a significant effect, ($n = 1517$, $g = 0.46$,

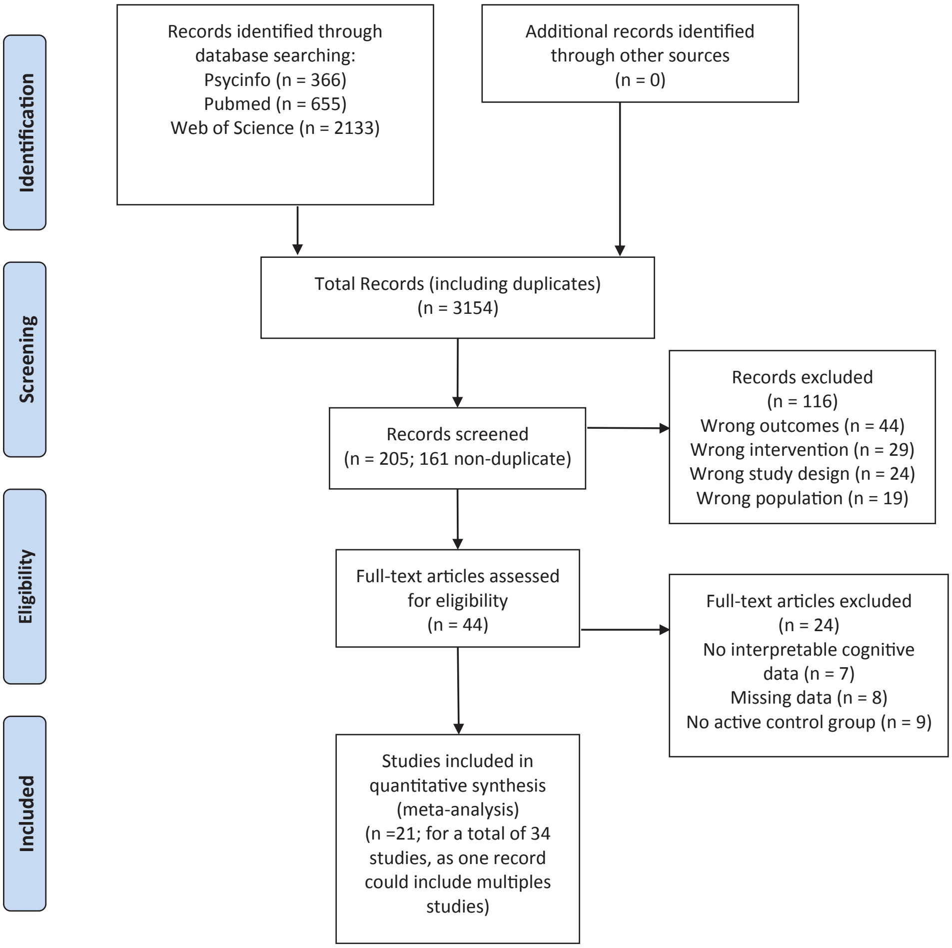

Fig. 2. PRISMA-style flowchart of the study selection process.

95% *CI* = 0.15–0.80, p = 0.008), but heterogeneity was high (Tau^2 = 0.26, I^2 = 89.7%).

3.5. Risk of bias across studies

The effect size of all included studies on cognitive outcomes corresponded to a z value of 4.64 ($p < .001$), indicating that 157 missing studies would be needed for the present results to be nullified, given that $\alpha = 0.05$. Assuming a random effect model, the Trim and Fill method revealed no missing (trimmed) studies (Fig. 12).

3.6. Additional analyses

3.6.1. Meta-regressions

Meta-Regression analyses showed that study quality was a positive moderator of the effect size, while the mean age of the sample, the percentage of females in the sample and induction duration were not (Table 3). However, an examination of the bubble plot (Fig. 13) revealed that three outliers appeared to drive the effect. When these studies were excluded from the analysis, the regression was no longer significant ($\beta = 0.4$, $SE = 0.04$, $p = .35$).

4. Discussion

4.1. Summary of evidence

The primary analysis revealed a small positive global effect of MAIs, suggesting that even a short attentional meditation practice can immediately improve cognitive functioning. These findings support the hypothesis that the observed improvement of cognitive functioning in experienced mindfulness meditators is attributable, at least partially, to the practice attentional meditation. While the exact long-term effect of mindfulness practice on cognition was not explored in the present review, these results represent substantial

Table 1
Cognitive domains addressed by included studies.

Cognitive domain	Definition	Number of studies[1]	Tasks
Attentional functioning		**10**	
Vigiliance	Vigilance refers to the cognitive state of being prepared to detect a stimuli (Petersen & Posner, 2012)	2	Inattentional blindness task
Sustained attention	Sustained attention refers to the ability to maintain focus on a task for an extended period of time (Fortenbaugh, et al., 2017)	4	NWRA, 20 + min educational video, SART, Meditation breath attention score, Backward counting, ANT
Selective attention	Selective attention refers to the ability to orient one's attention to a specific stimuli (Petersen & Posner, 2012)		Symbol digit modalities test, TMT A, Flanker task, SART, Filter task
Processing speed	Processing speed refers to the rapidity at which one can process stimuli. It was included in attentional functioning because it is arduous to make a clear distinction between selective attention processes and processing speed in tasks (Weiler et al., 2000)	2	Symbol digit modalities test, TMT A, Text retranscription
Executive functioning		**9**	
Switching/mental flexbility	Switching or cognitive flexibility refers to the ability to alternate between response sets, tasks and/or modality (Anderson et al., 2010)	4	TMT-B, Two-back, Task switch
Inhibition	Inhibition is the capacity to suppress or stop an automatic response or a cognitive process (McLeod, 2007)	7	Stroop, Flanker task, Emotional stroop, Go-No go task
Fluency	Fluency tasks are often in the verbal or graphic modality. They assess one's ability to efficiently generate appropriate responses (Brocki & Bohlin, 2004)	1	Verbal and graphic fluency
Memory		**15**	
Short-term memory	Short term memory is the ability to retain information for a few seconds (Cowan, 2008)	1	Forward span
Working memory	Working memory is the ability to not only retain information for just a moment but also manipulate it to recall the information according to specific rules (Cowan, 2008)	4	Backward span, N-back
Long-term memory	Long term memory is the ability to freely recall or recognize information encoded a couple of minutes or a long time ago (Cowan, 2008)	9	Word recognition, R-K task, Free information recall, Deese-Roediger-McDermott paradigm
Higher-order functions		**10**	
Verbal reasoning	Verbal reasoning is the ability to deduce an answer based on verbal and semantic information (Krumnack, et al., 2011)	3	Anagram resolution, Sentence reformulation
Judgement/decision making	Judgment and decision making is a complex cognitive function integrating various processes (eg. cost assessment) that leads an individual into making a decision (Weber & Johnson, 2009)	6	Sunk-cost bias task, Trust game, Harpen critical thinking assessment, Linguistic intergroup bias, Elderly bias
Creativity	Creativity, very simply put, is the ability to generate original solutions to a problem (Guilford, 1967)	1	Graphic fluency

[1] The sum of studies that addressed the cognitive functions and domains may not match since a task may involve more than one function.

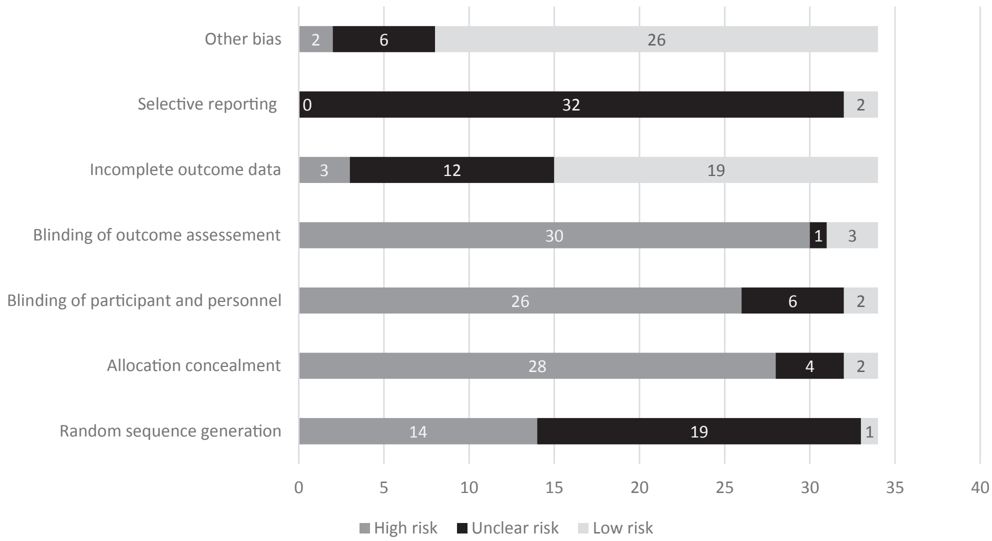

Fig. 3. Risk of Bias of individual studies.

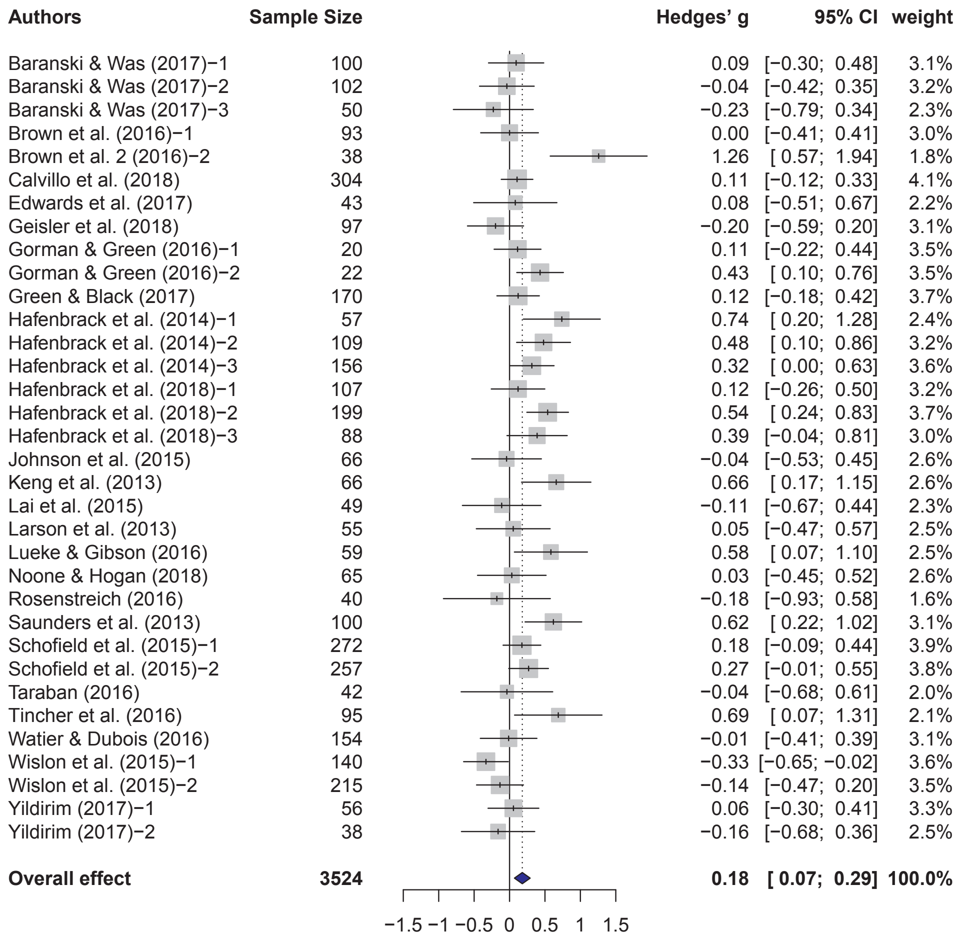

Fig. 4. Forest plot of the effect of all MAIs on overall cognition.

support for models that primarily consider mindfulness meditation as a form of mental training (Lutz et al., 2008; Tang et al., 2015; Vago & Silbersweig, 2012).

When exploring the effects of mindfulness by type of induction, only Mixed inductions revealed a significant effect. Note that the number of included studies that used an OM type of induction was low. Regarding the FA induction type, it is hard to conclude an absence of effect, as there was substantial heterogeneity. Thus, the analyses grouped by cognitive domains might be more informative.

Separate analyses were conducted on four cognitive domains (Memory, Attentional functioning, Executive functioning, and Higher-order functions). These analyses revealed a significant small effect on the Higher-order functions domain only, with no heterogeneity. Surprisingly, no effects were found on Attentional or Executive functioning, while most conceptual models of mindfulness state that meditation practice is primarily a form of attentional training that also heavily relies upon executive mechanisms such as cognitive inhibition (Hölzel et al., 2011; Lutz et al., 2008; Tang et al., 2015). Indeed, improvement in sustained and divided attention, cognitive inhibition and cognitive flexibility have been observed in individual who participated in MBSR programs or intensive mindfulness retreat (Chambers et al., 2008; Jha et al., 2007; Slagter et al., 2007) and in long-term meditators as well (Hodgins & Adair, 2010; Moore & Malinowski, 2009). It is possible that the benefits of mindfulness meditation on attentional networks or executive functions require longer and more frequent practice that cannot be detected with the induction design. It is also possible that the analyses were not sufficiently powered to detect such a small effect.

Nevertheless, the Higher-order functions domain, which presented a larger effect, was detected with similar statistical power. At first glance, this finding appears consistent with the hypothesis that mindfulness meditation could challenge and reduce biased forms of self-representations (Vago & Silbersweig, 2012). However, Vago & Silbersweig (2012) model states that this "debiasing" of the mind is possible because of the cumulative training of executive monitoring and inhibition, working memory, and attentional networks that occur during meditation. In short, the authors suggest that it is only possible to be aware of maladaptive beliefs and to disengage from them when attention is strengthened, and when the wandering mind is calmed.

This causal chain is in line with a meta-analysis by Sperduti et al. (2012), who describe the cascade of brain activations that unfold during both FA and OM meditation. They propose that the activation of self-monitoring and thought-monitoring networks

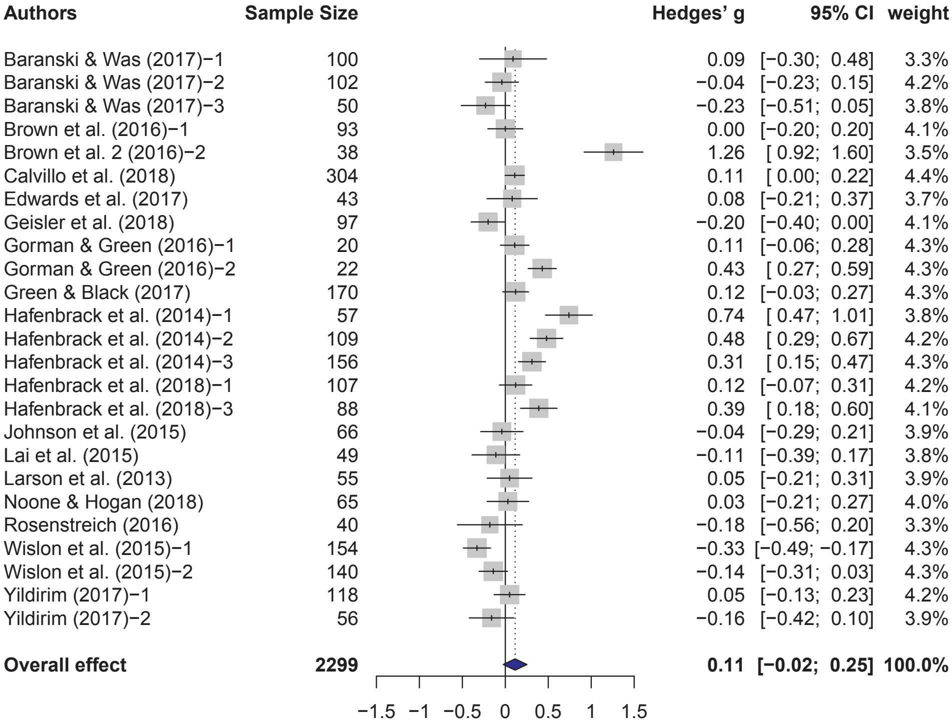

Fig. 5. Forest plot of the effect of FA induction on overall cognition.

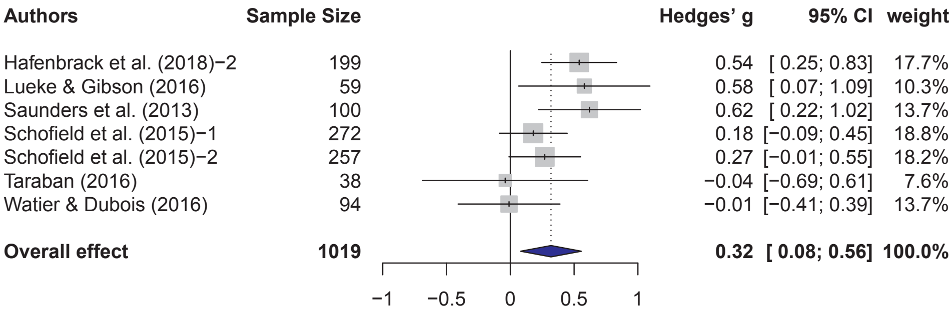

Fig. 6. Forest plot of the effect of Mixed induction on overall cognition.

Table 2
Statistics of the meta-analyses by cognitive domain.

Cognitive domain	*n*	*k*	*g*	95% *CI*	*p*-Value	*Tau*^{2}	I^2 (%)
Attention	923	10	0.13	−0.02 to 0.29	0.08	0.02	3.5
Executive Functioning	593	9	0.11	−0.09 to 0.30	0.24	0.04	34.7
Higher-Order Functions	1007	10	0.35	0.20 to 0.50	0.0005	0.02	0.0
Memory	1386	15	0.10	−0.10 to 0.30	0.32	0.11	61.2

(primarily formed by the medial prefrontal cortex and the anterior parahippocampus) are dependent upon the activation of the attention interference control network (primarily formed by the putamen and caudate nucleus). In sum, neuro-cognitive models based upon research on experienced meditators state that improvement in higher-order functions could be mediated by the improvement of other cognitive processes, particularly attentional functions. Therefore, it is surprising that the Higher-order functions domain is the only one to show an improvement after a MAI, among the other domains identified in the included studies.

Our results suggest that such models might not be representative of how the state of mindfulness is developed in new meditators practicing brief meditations. As it is generally difficult for new meditators enrolled in mindfulness programs to maintain their practice (Parsons et al., 2017), knowledge of the cognitive processes unfolding during the first meditation sessions could be key to develop better teaching methods (e.g. the MBI-TAC; Crane & Kuyken, 2018). For example, the present findings suggest that it might be easier

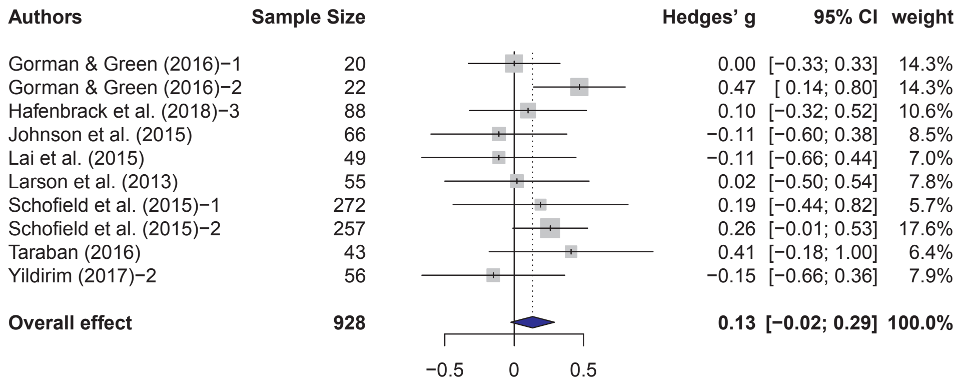

Fig. 7. Forest plot of the effect of MAIs on Attentional functioning domain.

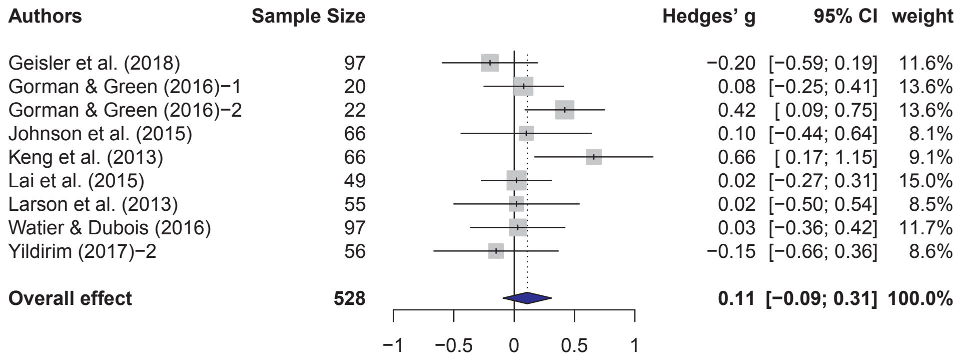

Fig. 8. Forest plot of the effect of MAIs on Executive functioning domain.

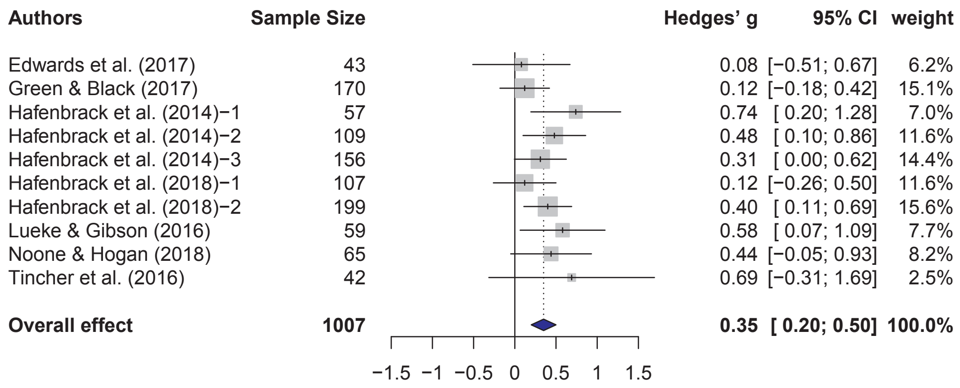

Fig. 9. Forest plot of the effect of MAIs on Higher-order functions.

for new meditators to apply instructions related to the observation of self-referential processes (e.g., to take note of the wandering mind), as opposed to instructions related to the orientation of attention (e.g., refocusing each time the mind wanders). This could also imply that OM is more accessible to novice meditators than FA, which contradicts the prominent hypotheses (again, based on expert meditator literature) that OM is typically harder than FA (Lutz et al., 2008; Vago & Silbersweig, 2012). This interpretation is, however, in line with Brewer et al. (2013), who stated that modern mindfulness programs put too much emphasis on attentional control and that curiosity toward *all* experiences should prevail over a strict FA practice.

However, much of the present interpretation must be nuanced by the fact that most of the studies included in our meta-analysis presented poor methodological quality. It is not surprising, considering that mindfulness research has been criticized for its lack of methodological rigor (Davidson & Kaszniak, 2015; Van Dam et al., 2018). While the critical commentary on research practices and researcher biases is by no means unique to the mindfulness literature (for detailed reviews, see Ioannidis, 2005; Munafò et al., 2017), those methodological limitations have critical implications on the validity of the present results. For example, the absence of double-blind procedures in the majority of the reviewed studies increases the risk that potential researchers or participants biases (i.e.,

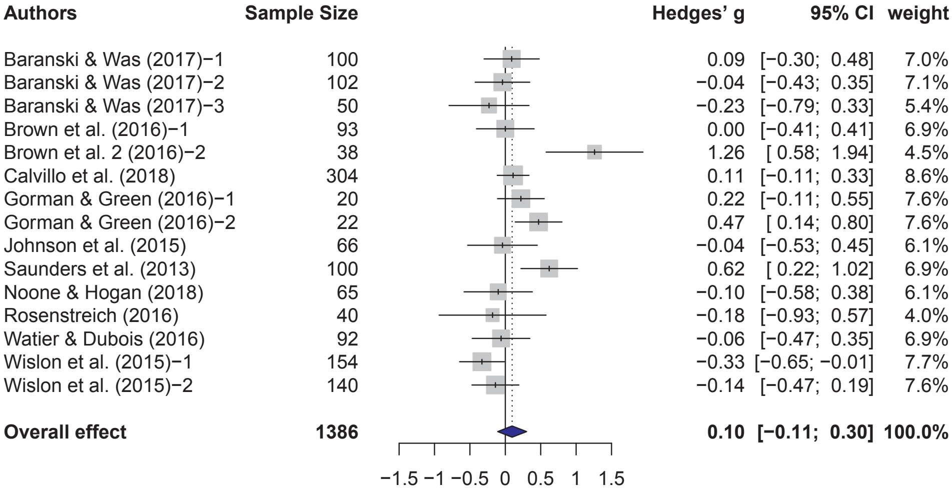

Fig. 10. Forest plot of the effect of MAIs on Memory domain.

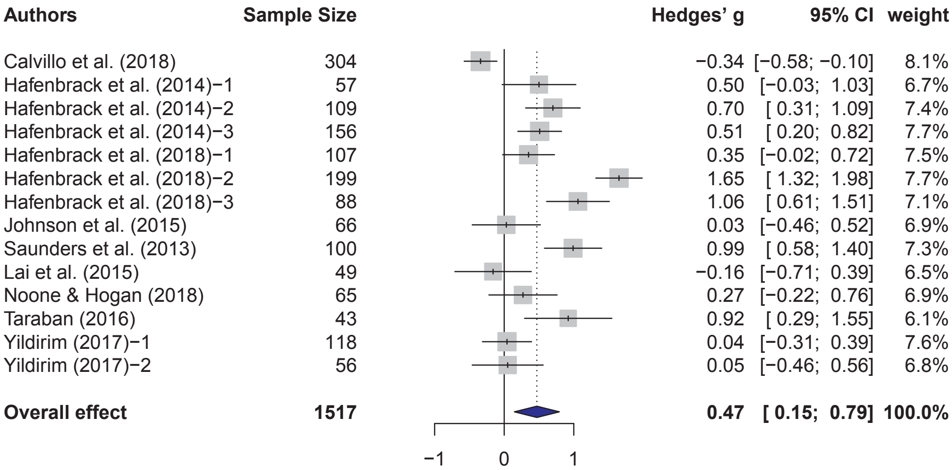

Fig. 11. Forest plot of the effect of MAIs on State Mindfulness.

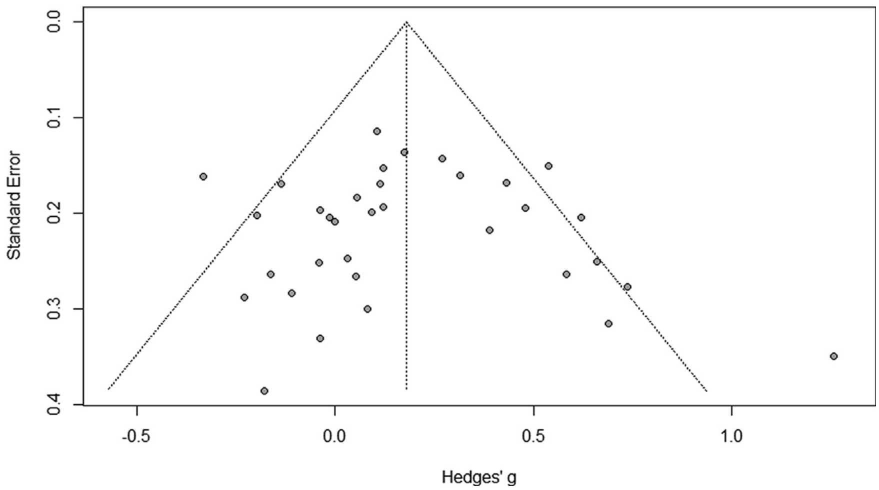

Fig. 12. Funnel plot of all the included studies.

Table 3
Meta-regressions statistics.

Moderator	*k*	*β*	SE	*p*-Value
Age	26	0.14	0.01	0.17
% of female	27	0.0008	0.006	0.90
Induction duration	32	−0.001	0.01	0.40
Study quality	34	0.002	0.23	0.019

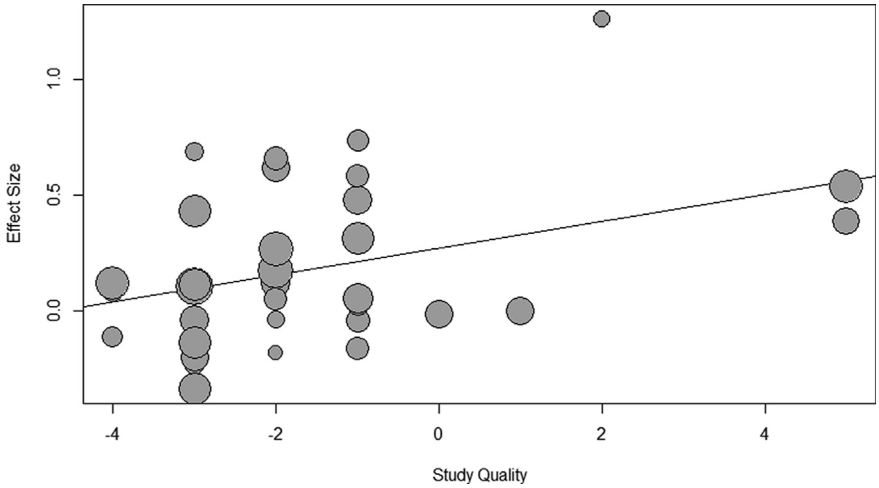

Fig. 13. Meta-regression with study quality as a moderator.

performance or detection bias; Higgins & Green, 2011) influenced the outcomes. While double-blinding may be challenging to implement in mindfulness research, feasible procedures do exist. Active control groups that mimic all components of a mindfulness intervention (see MacCoon et al., 2012; Schmidt et al., 2011; Williams et al., 2014) can realistically be implemented in experimental research, as demonstrated by a small portion of the reviewed studies (e.g., Johnson, Gur, David, & Currier, 2015; Noone & Hogan, 2018). These procedures (1) allow for the participants to remain blind to which treatment group is the focus of the research and (2) control for potential confounding effects (Davidson & Kaszniak, 2015). Moreover, for the researchers to remain blind to group assignment, Davidson and Kaszniak (2015) suggested that participants could follow instructions either distributed in sealed envelopes or delivered via a computer in a random and concealed fashion. Such good practices were rare in the reviewed studies. In sum, given the high risk of bias observed in the reviewed studies, the results of this meta-analysis should be considered with caution.

4.2. Limitations

A first potential limitation of the present report relates to the classification between the different types of mindfulness induction. While a formal decision tree guided this classification (see Fig. 1), the scientific literature has not yet produced objective criteria to determine the cut-off between FA and OM inductions, conceived as two poles of an attentional orientation continuum (Lutz et al., 2015). For example, it is unclear whether a body scan meditation should be considered as FA, OM, or Mixed type of induction. In the present review, body scans were generally considered as Mixed inductions. Body scan typically instructed participant to orient their attention toward specific body parts, but also included segments of broader and less directed forms of attention. However, in the absence of clear cut-off, it could also be argued that a body scan is primarily an FA exercise. This classification, therefore, involved some element of subjectivity.

Additionally, the tool used in this meta-analysis for assessing the risks of bias was initially developed in the context of randomized controlled trials (Higgins et al., 2011). Although it can easily be transposed to experimental designs, experimental papers in psychology do not typically report elements necessary for proper evaluation using the Cochrane Guidelines. As none of the included studies referred to a preregistered protocol, the reporting bias could not be assessed appropriately.

Moreover, we limited our investigation of the effects of mindfulness meditation on cognition to attentional mindfulness inductions. Other aspects of mindfulness practice could have been explored, as mindfulness is a rich practice that is also concerned with attitudes, ethical considerations and other complex psychological and emotional processes aiming at self-actualization (Bodhi, 2011; Brown, Ryan, and Creswell, 2007; Dahl, Lutz, and Davidson, 2015). For example, Dahl, Lutz, and Davidson (2015) suggested that mindfulness could also include practices aiming at cultivating attitudes associated with well-being, such as compassion, kindness, and patience. These other types of mindfulness practices could have different effects on cognition.

4.3. Future research directions

First, we recommend that researchers target their efforts on developing a better understanding of the cognitive processes involved in the very first stages of mindfulness meditation practices. The prominent cognitive models of mindfulness meditation are based on expert meditators literature (Lutz et al., 2008; Sperduti et al., 2012; Tang et al., 2015; Vago & Silbersweig, 2012) and are inconsistent with the present results. This highlights the need for cognitive research with novice meditator populations.

Second, the analysis of individual study biases revealed that most mindfulness induction methodological quality was poor. We urge researchers to adopt the same methodological rigor that is required of clinical studies by ensuring that randomization and blinding procedures are adequate and by reporting and justifying any participant exclusion. Moreover, we highly encourage the preregistration of study protocols. These recommendations are in line with recent commentaries on mindfulness literature (Davidson & Kaszniak, 2015; Van Dam et al., 2018) and, more generally, broad methodological critics of the current practices in scientific research (Munafò et al., 2017).

Finally, in the process of choosing a cognitive assessment tool, researchers must consider its construct validity. As cognitive functions work closely together and interact to perform a task (Miyake and Friedman, 2012), it appears impossible to create an assessment tool that purely evaluates a single function. So, based on Miyake and Friedman's (2012) recommendations, we suggest utilizing multiple validated tasks and converging the results to interpret the scores related to a single function. Furthermore, when trying to assess the impact of mindfulness meditation on cognitive functions, it is essential to ensure that the tasks assess the aimed ability, as very liberal uses and interpretations of clinical neuropsychological tests were observed in some of the studies included in this meta-analysis.

5. Conclusion

In this systematic review and meta-analysis, we aimed at examining the effect of mindful attention induction on cognitive functioning. A small positive effect was observed on overall cognitive processes, with acceptable heterogeneity. Focused Attention induction showed no effect, while the number of Open Monitoring studies was insufficient to conduct analyses. However, there was a significant effect for Mixed induction. Finally, inductions only had a significant effect on the Higher-order Functions, while Memory, Attentional, and Executive Functioning showed no significant improvement. The methodological quality of the studies was poor, limiting the confidence in the interpretation of the results. Future studies should implement additional measures to reduce possible biases.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.concog.2020.102991.

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