Mindfulness Enhances Cognitive Functioning: A Meta-Analysis of 111 Randomized Controlled
Trials

Nur Hani Zainal, Ph.D.

Harvard Medical School

Michelle G. Newman, Ph.D.

The Pennsylvania State University

Author Note

To whom correspondence should be addressed: hani.bzainal@gmail.com

First Author: Nur Hani Zainal

Affiliation: Harvard Medical School

Address: 108 Longwood Ave, Boston, MA 02115

Co-Author: Michelle G. Newman

Affiliation: The Pennsylvania State University

Address: 371 Moore Building, University Park, PA 16802

This paper has not been peer-reviewed. Please do not copy or cite without the author's permission.

Declarations of conflict of interest: none.

Acknowledgments

We sincerely thank Drs. Nicole Anderson, Micela Balconi, Peter Malinowski, Michael Mrazek, Martin Prätzlich, Benjamin Schöne, Rob H.J. van der Lubbe, and Kathleen Walsh for providing descriptive data of the means and standard deviations of scores on all cognitive test(s) administered in their study at all time-points upon request. We also thank Dr. Mike Cheung at the National University of Singapore for offering statistical consultation to refine our Method section. We also wish to express gratitude to our 16 undergraduate research assistants – Ana Clever, Alexa Belnick, Armani Moore, Emma Win, Emily Forcht, Isabella Gonzalez, Jamie Gensbauer, Kathryn Miller, Madeline Lamonica, Madison Yeoman, Natalie Gottret, Natalie Suzette, Noor Lamba, Serena Chen, Shannon McGovern, and Vivian Nguyen – who served as reliability coders on the team and who regularly attended meta-analysis meetings to resolve any observed discrepancies between ratings.

Abstract

Background: In theory, habitually exercising mindfulness skills can improve cognitive functioning abilities. However, no comprehensive quantitative reviews of the efficacy of MBIs on global and unique cognitive subdomains exist to date. **Method:** This meta-analysis examined the effects of MBIs on global cognition and 15 cognitive subdomains. Inclusion criteria: meditation naïve participants; participants randomly assigned to MBIs or no-treatment, waitlist, or active control; outcome measures included at least one behavioral cognitive assessment or subjective cognitive functioning measure; teaching mindfulness skills was the primary treatment focus. Exclusion criteria: inadequate data to calculate effect sizes; MBIs included only one session; control condition that contained any MBI form. Robust variance estimation and moderator analyses controlling for presence of reported treatment fidelity were conducted. **Results:** One-hundred-and-eleven RCTs ($n=9,538$) met eligibility criteria. MBIs had small-to-moderate significant effects on global cognition, executive attention, WM accuracy, inhibition accuracy, shifting accuracy, sustained attention, and subjective cognitive functioning (average $g = 0.257-0.643$ versus waitlist/no-treatment; average $g = 0.192-0.394$ versus active controls). MBIs did not impact executive functioning (EF) latency indices, verbal fluency, processing speed, episodic memory, and cognitive error. Treatment effects were stronger for those with elevated psychiatric symptoms compared to healthy controls, and medical samples, studies with completer (vs. intent-to-treat) analysis, face-to-face (vs. self-guided) delivery, and use of standard mindfulness-based stress reduction or mindfulness-based cognitive therapy (vs. non-standard MBI). **Conclusion:** MBIs consistently yielded small-to-moderate yet clinically meaningful effect sizes on global cognition and six cognitive subdomains that captured accuracy versus latency-based indices of EF and sustained accuracy.

Word count: 249

Keywords: mindfulness-based interventions; cognitive functioning; randomized controlled trials; meta-analysis; executive function

Mindfulness Enhances Cognitive Functioning: A Meta-Analysis of 111 Randomized Controlled Trials

Mindfulness is described as the effortful and continual process of non-judgmentally focusing on experiences in the here and now in flexible, curious, and receptive ways (Bishop et al., 2004). Originating from Buddhist philosophies and meditative practices, scientific comprehension of mindfulness meditation has grown in the past 30 years (Creswell, 2017). In particular, abundant evidence has shown that mindfulness-based interventions (MBIs) positively affect various health outcomes across diverse age groups, genders, and people living in different cultural contexts. Children, adolescents, as well as young (aged 18 to 40 years), middle-aged (41–64), and older adults (65 years and older) who underwent MBIs experienced neurophysiological or self- and other-rated improvements in physical immunity, inflammation levels, cardiovascular indices, mood regulation, flexible thinking, and perspective-taking (Abbott et al., 2014; Black & Slavich, 2016; Flook et al., 2015; Flook et al., 2010; Kaunhoven & Dorjee, 2017; Wetherell et al., 2017). Advancing our understanding of potential mechanisms via which mindfulness confers benefits is thus essential.

One of the multiple viable mechanisms via which mindfulness confers benefits include improved *executive functioning* (EF; i.e., higher complex cognitive control functions responsible for governing cognitive and behavioral processes). It has been thought that teaching focused attention (FA) and open monitoring (OM) exercises through MBIs might enhance various EF abilities (Stein & Witkiewitz, 2020). FA training involves intentionally maintaining attention to a particular object or aspect of experience (e.g., bodily sensations, slowed breathing rhythms) and continually re-focusing after each momentary distraction (Anālayo, 2019a). OM practices comprise engagement in non-judgmental and non-elaborative awareness with acceptance and

curiosity (Uusberg et al., 2016). Moreover, recurrently engaging in OM is theorized to improve the sustained posture of non-reactivity toward the ebb and flow of cognitive content and emotional intensity within the field of awareness (Anālayo, 2019b). These processes are thus plausible distinct mechanisms of how FA and OM may benefit EF domains. Repeatedly practicing FA and OM has been theorized to positively impact *working memory* (WM; adeptness to continually monitor environmental input and replace out-of-date information with new information; Jha et al., 2019; Miyake et al., 2000; Vago et al., 2019). Relatedly, by strengthening emotion regulation abilities (Raffone et al., 2019), OM might refine meta-cognitive processes that enhance WM capacity (Lutz et al., 2015).

Furthermore, detaching from unhelpful thoughts via FA exercises has been argued to strengthen other EF subdomains apart from WM (Corbetta & Shulman, 2002). Theoreticians (Raffone & Srinivasan, 2017) have asserted that practicing FA increases versatility to change and resets the *shifting* and *inhibition* EF facets. *Shifting* is defined as the capacity to switch back and forth between distinct thinking modes fluently (Berg, 1948; Chiu et al., 2018), and *inhibition* is defined as the ability to refrain from autopilot response tendencies effortfully (Jewsbury et al., 2016). Practicing FA can foster these benefits primarily if attention has been directed away from unhelpful thoughts (e.g., brooding, craving, obsessions) and toward the here and now and task at hand (Wolkin, 2015).

On that note, mindfulness practices might improve various aspects of attentional control (basic ability to regulate mental focus on tasks consistent with a desired aim; Sorensen et al., 2018), given how it is a foundational precursor to EF (Vilgis et al., 2015). For example, it has been proposed that MBIs can improve meta-cognition and related attentional facets (Haigh et al., 2010). These facets include *sustained attention accuracy* (degree of correctness and consistency

with staying on-task; Esterman & Rothlein, 2019) and *intra-individual coefficient of variation* (degree of variability in offering accurate responses on sustained attention tasks; Bellgrove et al., 2004; Cubillo et al., 2023). *Sustained attention* has also been defined as *alerting* (essential arousal or awareness of objects; Prakash et al., 2020). Further, recurrently identifying distracting thoughts has been theorized to buttress the salience attentional control subdomain (Seeley et al., 2007). Salience is defined as the identification of or goal-driven fixation on specific visual or physical cues (Awh et al., 2012). Directing attention back to the task after distractions could also augment the *orienting* ability (honing focus on an object amid diverse sensory input or *selective attention*; Ristic et al., 2007; Sood & Jones, 2013). Such mindfulness practices could also enhance *executive attention* (ability to skillfully manage responses in the face of conflicting thoughts, emotions, and responses or *conflict monitoring*; Petersen & Posner, 2012). Taken together, these theories postulate that MBIs skills may enhance various attention domains by improving observational, discernment, and psychological flexibility strategies and raising awareness of varying factors influencing events (Cubillo et al., 2023; Garland et al., 2015).

Beyond EF and attentional constructs, MBIs could impact other cognitive functioning domains. As the capacity to describe ongoing internal experiences (e.g., feelings, thoughts) and external events by intentionally using precise and expressive wording is conceptualized as an aspect of trait mindfulness (Baer et al., 2004), MBIs could plausibly enhance *verbal fluency*. *Verbal fluency* is defined as the capacity to generate as many relevant words based on a cue (e.g., semantic category, letter) within a time limit (Henry & Crawford, 2004; Raucher-Chéné et al., 2017). Relatedly, MBIs could reduce *cognitive errors* (mistakes by commission or omission; Fetterman & Robinson, 2011) during task engagement, given repeated attempts to concentrate on present experiences despite occasional mind wandering (Lindsay & Creswell, 2017; Teper et al.,

2013). Further, it has been theorized that practicing MBIs helps people learn to ignore distractions (Posner et al., 2015) and reduces repetitive negative thinking, such as worry and rumination (Gu et al., 2015). By simultaneously reducing repetitive thinking and freeing up more cognitive resources to attend to and process incoming information, MBIs could enhance *processing speed* (degree of task completion efficiency; Muller et al., 2021). As the quality of engagement with and attention to tasks increase via MBIs, other theorists (Brown et al., 2016) assert that these skills could extend to improving *episodic memory* (capacity to correctly recall previous events, facts, and information with their situational context; Allen & Fortin, 2013; Tulving, 2002). Theorists (Lindsay & Creswell, 2017; Teper et al., 2013) have additionally proposed that MBI-related enhancements in awareness and acceptance of events in one's experiential field may improve *subjective cognitive functioning* (perceived degree of ability to stay focused on task, process information, memorize facts, and exercise other cognitive functioning faculties; Daglas-Georgiou et al., 2022; Hallion et al., 2019). By *cognitive functioning*, we mean performance effectiveness of mental processes of attention, awareness, comprehension, intuition, judgment, language, learning, memory, perception, and reasoning (Fisher et al., 2019). Collectively, these preceding models propose that MBIs, compared to no-treatment or waitlists, can refine specific cognitive subdomains and *global cognition* (composite of all said cognitive subdomains herein) by freeing up limited resources and enabling effective and efficient use of them.

Thus far, 16 systematic reviews have examined if MBIs augmented global cognition and specific cognitive subdomains. Data from 34 experiments revealed that a single-session FA or OM could enhance global cognition and higher-order cognitive functioning (Gill et al., 2020). Nonetheless, these brief inductions did not improve attention and EF facets, such as inhibition

and shifting. Chiesa et al. (2011) examined 23 trials that included a mixture of controlled, randomized controlled, and cross-sectional (meditator vs. non-meditator) studies. They concluded that meditative mindfulness exercises did not impact episodic memory. However, meditative mindfulness practices were linked to better global cognition, attentional control, and specific aspects of EF, including WM and verbal fluency. In another qualitative review, Gallant (2016) observed that across 14 open and controlled trials, MBSR and MBCT consistently improved the EF facet of inhibition but not shifting and WM. However, cross-sectional and open-trial studies do not rigorously establish cause-effect relations and preclude ruling out other confounds (Kazdin, 2017).

Eight additional systematic reviews examined randomized and non-randomized controlled trials. These reviews found that combining studies of meditation and MBIs (Eberth & Sedlmeier, 2012) or focusing solely on MBSR or MBCT (Lao et al., 2016) benefitted global cognition, attention, EF facets, intelligence, and autobiographical memory in adults. Also, in 40 trials ($n=2,172$) among healthy adults, MBIs positively affected inhibition, WM, and shifting accuracy (Verhaeghen, 2021). Further, in 25 MBIs ($n=1,439$), Im et al. (2021) observed small substantial effects on global EF, but not attention, WM, and long-term memory, among clinically-disordered and healthy adults. Similar benefits were found in children and adolescents when combining studies using yoga, meditation, and MBIs (Mak et al., 2018) or focusing only on MBSR or MBCTs (Zoogman et al., 2015). Another review of RCTs, quasi-experiments and non-randomized MBIs (number of included studies (k)=29, $n=1,414$) observed that group-based MBIs enhanced global EF, inhibition, WM, and verbal fluency (Millett et al., 2021). Relatedly, a recent systematic review ($k=24$ comprising nine non-randomized MBIs and 15 MBI RCTs) observed that MBIs positively impacted subjective cognitive functioning for patients with cancer

(Flynn et al., 2023). However, mixing randomized and non-randomized controlled trials can produce unreliable effect sizes and confidence intervals due to self-selection biases and systematic baseline between-group differences (Reeves, 2008).

To date, only six meta-analyses focused solely on RCTs. For example, across 13 RCTs ($n=1,112$), MBIs had substantial, moderate effects on WM and inhibition but a negligible impact on shifting among adults (Cásedas et al., 2020). In children and adolescents, across 17 studies ($n=1,762$), MBIs led to small but meaningful effects on attentional control and global EF (e.g., planning, WM; Dunning et al., 2019). Also, seven RCTs ($n=170$) found positive impacts of MBIs (vs. control) on attention and episodic memory among persons with multiple sclerosis (Han, 2021). Relatedly, across 27 MBI RCTs ($n=1,632$), MBIs had small yet significant effects on attention and global EF, but not WM, among healthy adults ages 18-65 (Yakobi et al., 2021). However, these reviews did not consistently examine the effects of MBIs on EF facets and executive attention. Also, data synthesized across nine studies ($n=724$) showed that MBIs did not notably impact attention, EF, memory, and global cognition in adults aged 60 years and above (Sanchez-Lara et al., 2021). Most recently, across 56 independent studies ($n=2,931$), MBIs displayed superior effects on global cognition, EF, and WM, compared to no-treatment but not active controls (Whitfield et al., 2022).

Overall, previous reviews had several gaps the current meta-analysis was designed to fill. First, beyond methodological limitations related to most of them, such as including uncontrolled or non-randomized studies, only two (Verhaeghen, 2021; Whitfield et al., 2022) tested if MBIs exerted differential effects on attentional control subdomains – alerting (or sustained attention), orienting, and executive attention. These attentional control domains should be examined separately as MBIs could influence them differently, given that they are neurologically

dissociable despite their inter-connectedness (Posner & Rothbart, 2007). Further, prior MBI meta-analyses (Im et al., 2021; Verhaeghen, 2021) that examined moderators tended to test their effects only on global cognition. Since moderator effect sizes might be domain-specific, the current meta-analysis can provide more information by testing potential treatment and moderator effects on different cognitive functioning domain outcomes. In addition, to our awareness, no reviews have investigated whether MBIs influenced processing speed, subjective cognitive functioning, and cognitive error, despite the theories above suggesting those possibilities. Also, it may be helpful to test the effects of MBIs on both objective (performance-based) cognitive functioning domains and subjective (self-reported) attentional control, as these aspects of cognitive functioning might not align (Vago et al., 2019; Van Dam et al., 2018). Doing so also permits examining if MBIs affected accuracy- more than latency-based markers of EF.

Additionally, no prior reviews have investigated whether instructor-led face-to-face (vs. self-guided) MBIs were more potent at changing cognitive outcomes. This question is becoming more important given the recent rise in mostly low-intensity self-help digital MBIs (Mrazek et al., 2019). Relatedly, most prior meta-analyses of MBIs have not tested if gender, study quality, retention percentage, and completer (vs. intent-to-treat; ITT) analyses would moderate the impact of MBIs on cognitive functioning. Such efforts are necessary to determine under which conditions MBIs would be of benefit. Also, as lack of attention to treatment integrity is a field-wide major limitation concerning the state of science on this topic (Crane & Hecht, 2018), our meta-analysis adds to prior ones by including the presence of reported treatment fidelity checks as a covariate. In addition, whereas most prior meta-analyses had restricted age ranges, we tested the main and interaction treatment effects of MBIs on cognitive functioning across the lifespan. Also, we examined only MBI RCTs and had 95 (Cásedas et al., 2020), 84 (Yakobi et al., 2021),

and 55 (Whitfield et al., 2022) more studies than recent RCT-focused ones, and 71 (Verhaeghen, 2021) and 76 (Im et al., 2021) more studies than recent quantitative reviews that synthesized effect sizes from randomized and non-randomized controlled MBIs. Our efforts thus offer a more accurate, comprehensive, and up-to-date review. Additionally, the current meta-analysis adds to the literature by examining the impact of MBIs on global cognition at follow-up time points.

Considering the above, an up-to-date systematic quantitative review was conducted to quantitatively synthesize 111 RCTs ($n=9,538$) to assess the strength of the effect of MBIs on global cognition and the following unique cognitive subdomains: orienting, executive attention, WM accuracy and latency, inhibition accuracy and latency, shifting accuracy and latency, sustained attention (accuracy or intra-individual coefficient of variation), subjective cognitive functioning, processing speed, verbal fluency, episodic memory, and cognitive error. We selected these 15 subdomains because there was sufficient RCT literature to conduct a meta-analysis. Doing so can catalyze future efforts to advance the field on this topic by examining the effects of MBIs on other understudied cognitive subdomains, such as decision-making (Fernando et al., 2016; Kirk et al., 2016), inductive reasoning (Shapiro et al., 2012), language (Dickinson et al., 2016), and delay discounting (MacKillop et al., 2011). Moreover, as previous reviews arrived at varying conclusions, this systematic review tested factors that may have moderated the strength of the effect of MBIs on unique cognitive subdomains.

Method

Search

Search terms and databases. This meta-analysis was carried out using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA; Moher et al., 2009) and was registered with the International Prospective Register of Systematic Reviews (PROSPERO;

#CRD42020220576; <https://tinyurl.com/5bhrmnub>). We defined eligibility criteria and methods before the search and selection process and continually documented these steps in a study protocol. Relevant studies were identified by searching five databases (ScienceDirect, PubMed, PsycINFO, Google Scholar, and Cochrane Library). Search dates included all articles that met eligibility criteria from January 1989 to December 2022. We used the following keyword combinations: “mindful*,” or “mindful* training” or “meditation” and “cognition,” “attention,” “executive attention,” “cognitive control,” “shifting,” “switching,” “inhibition,” “inhibitory control,” “cognitive flexibility,” “working memory,” “verbal fluency” and “randomized controlled trial” or “RCT.” Further, we systematically searched through reference sections of articles pertinent to our research question and eligible studies. To reduce the odds of publication bias (i.e., file drawer problem; Rosenthal, 1979), we included unpublished master’s theses and doctoral dissertations that met eligibility criteria. Moreover, we searched for potentially eligible articles via PsyArXiv Preprints and requested eligible data from pertinent society listservs.

Screening process. Eligibility criteria included: (1) sample comprised meditation naïve participants; (2) random assignment to MBIs vs. no-treatment, waitlist, or active control; (3) administration of at least one behavioral cognitive assessment, or subjective cognitive functioning measure at baseline and post-treatment; (4) teaching mindfulness skills was the primary focus of treatment (Creswell, 2017). Specifically, MBIs had to include psychoeducation and FA or OM skills delivery. (5) MBIs had to include at least two sessions (note that number of sessions was also examined as a moderator). Also, homework was prescribed.

We excluded studies if: (1) data was inadequate to calculate effect sizes; (2) they used acceptance and commitment therapy, dialectical behavior therapy, integrative mind-body training, loving-kindness meditation, neurofeedback mindfulness training, mantra-based training,

hatha yoga, or mindfulness-oriented yoga, self-compassion training, were augmented with aromatherapy or (3) a control condition contained any form of MBIs or MBI components (see Figure 1 for PRISMA flowchart).

Coding Procedures

We double-coded studies ($k=111$) for participant attributes (e.g., age, percentage of female), clinical status (i.e., healthy control (HC), participants with elevated psychiatric symptoms (PSY) or medical/physical illness symptoms (MED)), treatment attributes (e.g., number of sessions, number of session hours), active (cognitive-behavioral therapy (CBT), cognitive training, psychoeducation-only, or treatment-as-usual (TAU) that involved some intervention) vs. no treatment or waitlist control condition, self-guided vs. teacher-led, standard (defined as MBSR or MBCT) vs. non-standard MBI, study attributes (study quality, presence of fidelity checks, retention percentage), and cognitive function outcome attributes. The first author coded and extracted data from all studies. A second coder from a research team of 16 also independently coded for reliability. Thus, two coders rated and extracted each independent report under consideration. All coders underwent a standardized and rigorous training protocol that involved a mixture of didactics, regular meetings, consultations, and literature reviews. Discrepancies were resolved via regular discussion, and coders reached an agreement regarding a final set of codes.

Study quality. We evaluated study quality based on an adapted version of the Delphi criteria (Verhagen et al., 1998). The modified criteria were: (1) randomization conducted, (2) individuals in both conditions were demographically alike, (3) eligibility criteria defined, (4) experimenters who administered cognitive function measures were uninformed of treatment allocation, (5) sufficient descriptive statistics (e.g., mean and standard deviations at all periods)

were reported or available upon request to compute effect sizes for pre-to-post treatment changes, (6) ITT analysis used. Fulfilling each criterion received one point (vs. a zero). The Delphi score thus ranged from 0 to 6. In addition, this Delphi score study quality rating was used in the moderator analysis.

We also assessed study quality using the Cochrane Collaboration risk of bias instrument (Higgins et al., 2011). We coded “low risk,” “some concerns,” or “high risk” for biases linked to inadequate randomization steps, a departure from intended treatment protocols, missing data, outcome measurement, and selection of reported findings. Randomization bias reflected awareness of the condition before treatment assignment and baseline differences between treatment conditions. Bias arising from aberrations from intended treatment was coded if any protocol aberrations likely influenced the outcome, if existing aberrations were unbalanced between groups, if completer (or per-protocol) instead of ITT analysis was used, or if participants were analyzed in the incorrect group. Bias due to missing outcome data was coded if problems arose related to unavailable data biased findings, and missing data patterns were related to the parameter estimates. Measurement outcome bias was coded if there was evidence for the inappropriateness of assessments and if evaluators were aware of participants’ treatment assignments. Selection bias was noted if inferential outcome statistics were reported in the results, but complete descriptive statistics of cognitive function at pre- and post-treatment were omitted or unobtainable upon request or if a subset of an entirely administered cognitive battery was reported without a valid reason.

Measurement Properties

Cognitive data were coded for global cognition and 15 cognitive subdomains: orienting, executive attention, WM accuracy or latency, inhibition accuracy or latency, shifting accuracy or

latency, sustained attention (accuracy or intra-individual coefficient of variation), subjective cognitive functioning, processing speed, verbal fluency, episodic memory, and cognitive error. Table 1 provides information on the definitions of global cognition and the 15 cognitive subdomains examined in the current meta-analysis and the different types of tests classified in each cognitive subdomain. The online supplementary materials (OSM) detail the specific measures used for each cognitive subdomain and their psychometric properties.

Planned Analyses

All analyses were conducted in *R* Version 4.0.1. Inter-rater agreement was established with the *irr* package in *R* (Gamer et al., 2007). The *R* packages *robmeta* (Fisher et al., 2017), *metafor* (Viechtbauer, 2010), and *ggplot2* (Wickham, 2016) were used to examine treatment effects, study heterogeneity, outliers, and publication bias, and to create funnel and forest plots. *R* syntax of analyses is available on Open Science Framework.

Reliability. We established inter-rater agreement by computing two-way intra-class correlation coefficients (ICCs) for continuous variables (Shrout & Fleiss, 1979) and unweighted Cohen's kappa (κ) for all binary or nominal variables (Hallgren, 2012).

Effect sizes. Due to the diversity of studies, such as the varying number of treatment comparators (1–2) and cognitive outcome measures, we applied a random effects model (Borenstein et al., 2009). Further, we used robust variance estimation (RVE) with small sample adjustments to account for the non-independence of effect sizes clustered within the same samples and for studies with multiple treatment comparators (Tanner-Smith et al., 2016). Moreover, these RVE approaches produced effect size and 95% confidence interval (CI) estimates that account for effect size dependency. Effect sizes were coded such that higher values signified better cognitive outcomes.

Based on random-effects models using pre- and post-treatment data between groups, we computed Hedge's g to obtain accurate and unbiased parameter estimates (e.g., correcting for biases due to small sample size) using the following formula:

$$g = \frac{(\Delta TREAT)_{PRE-POST} - (\Delta CON)_{PRE-POST}}{S_{POOLED}} \times \left(1 - \frac{3}{4(df)-1}\right) \text{ and } S_{POOLED} = \sqrt{\frac{(n_{TREAT})SD_{CON}^2 + (n_{CON})SD_{TREAT}^2}{(n_{TOTAL}-2)}}.$$

For this formula, $(\Delta TREAT)_{PRE-POST}$ and $(\Delta CON)_{PRE-POST}$ are the average pre- to post-score change in treatment and control groups, n is the sample size, and SD is the standard deviation of post-treatment scores. Note that $(\Delta TREAT)_{PRE-POST}$ and $(\Delta CON)_{PRE-POST}$ were each computed using the formulas $\left(\frac{\bar{M}_{POST} - \bar{M}_{PRE}}{SD_{DIFF}}\right) \sqrt{2(1-r)}$ where $\bar{M}_{POST}$ and $\bar{M}_{PRE}$ are the post- and pre-treatment sample means, respectively, SD_{DIFF} is the standard deviation of difference, and r is the pre-post correlation. As the pre- and post-correlation were not obtainable, we used a conservative estimate ($r=.50$) representative of the retest reliability of cognitive functioning tasks reported in the literature to date (Dai et al., 2019; Hedge et al., 2018). A similar approach was used for global cognition to calculate pre-follow-up treatment effect sizes (MBIs vs. waitlist or no-treatment and MBIs vs. active controls).¹ Moreover, we controlled for the presence of reported treatment fidelity checks in all effect size analyses.

We also contacted 15 authors for these descriptive statistics. Of these, nine responded. When we could not obtain the descriptive statistics, other inferential statistics (e.g., p , t , F) that permitted computing effect sizes based on pre-and post-treatment values (i.e., condition $\times$ time interaction) were calculated following recommendations by the Cochrane Collaboration (Higgins

¹ We calculated the pre-follow-up effect size only for global cognition because there were insufficient studies to synthesize effect sizes based on the 1 global cognition and 15 cognitive subdomains examined herein.

& Green, 2011). Effect sizes based on change scores (vs. post-treatment scores) are less affected by possible baseline differences (Johnsen & Friberg, 2015). Sampling variance was computed as the sum of variances for the treatment group and control Group (Morris & DeShon, 2002, p. 117). Hedge's g effect sizes were standardly construed as follows: 0.2 (small), 0.5 (moderate), 0.8 (large). In addition, Pearson's r -effect sizes were interpreted based on convention: 0.1 (small), 0.3 (moderate), 0.5 (large; Durlak, 2009).

Outliers. Outliers were defined as effect sizes with studentized deleted residuals more than ± 1.96 and Cook's distance greater than the 50th percentile (Viechtbauer & Cheung, 2010). Sensitivity analyses tested if results remained the same with and without outlier(s).² All findings in the current manuscript excluded outliers, as outliers estimate the population average as distinct from the average calculated from the remaining effect sizes. In total, six outliers were deleted.

Study heterogeneity. To assess effect size heterogeneity, we used the I^2 and Q statistic. I^2 represents the degree of heterogeneity of the true observed dispersion. It estimates the proportion of variance due to between-study variability instead of within-study sampling error. I^2 values of 25%, 50%, and 75% were considered small, moderate, and large, respectively (Higgins et al., 2003). A statistically significant Q statistic suggests that variability around the average effect size is higher than would be solely predicted from sampling error (Cochran, 1954). Due to diverse sample attributes, treatment comparators, and treatment attributes across studies, some heterogeneity was expected. Importantly, significant heterogeneity indicated by the Q statistic was required before conducting moderator analyses.

² A similar pattern of results was attained when the analysis was carried out with and without the 6 outliers.

Publication bias. We assessed publication bias using the *p*-uniform test (van Assen et al., 2015) and inspected the funnel plots. Funnel plots illustrate publication bias by mapping each study's effect size with its standard error, such that more significant asymmetry indicates more risk of bias. Figures S1a to S17b in the Supplementary Materials provide funnel plots for all cognitive outcomes.

Results

Inter-rater agreement

At the screening stage, high levels of inter-rater agreement were observed for both continuous ($ICC=.983$) and categorical outcomes ($\kappa=.978-.992$). Likewise, at the data extraction stage, we found strong levels of inter-rater agreement for continuous ($ICC=.960-1.000$) and categorical outcomes ($\kappa=.939-1.000$). All item scores thus showed an excellent level of agreement. Fidelity checks were present in 64% of studies comparing MBIs to waitlist and no-treatment and 65% of studies comparing MBIs with active controls.

Sample characteristics

Table S1 presents study characteristics. Collectively, they included 9,538 participants with an average age of 33.98 years ($SD=20.05$, range=3.92–80.61, and of which 57.85% were female). The sample size ranged from 14 to 424, and the mean sample size was 84. Number of sessions ranged from 2 to 90 ($M=57.85$, $SD=19.81$). RCTs were conducted across 22 nations, most in the United States ($k=46$, 41.44%). Tables 2 and 3 present statistics of age, percentage of females, study quality, and the number of treatment sessions compared to no-treatment and waitlist controls or active control (Table S2). Forty-one out of 111 studies (36.94%) reported ethnicity, and in these studies, 60.93% of participants identified as White. No studies reported sexual orientation/gender identity. Concerning socioeconomic status, six studies recruited

participants with low income and three with low socioeconomic status. Across the five studies that reported income figures, mean annual income ranged from \$50,000 to \$124,000. Table S1 also includes education information. Also, the number of effect sizes for each independent study sample ranged from 1 to 39, with a mean of 6 effect sizes per study.

Effect of MBIs on Cognitive Domains Compared to No-Treatment or Waitlist Control

Effect size heterogeneity. Significant moderate-to-large effect size heterogeneity was observed for global cognition, WM accuracy, WM latency, inhibition accuracy, processing speed, and cognitive error (Table 2). Comparatively, no significant effect size heterogeneity was found for orienting, executive attention, inhibition latency, shifting accuracy, shifting latency, sustained attention accuracy, intra-individual coefficient of variation, subjective cognitive functioning, verbal fluency, and episodic memory.

Cognitive outcome effect sizes. Table 2 and Figure 2 show the effects of MBIs (vs. controls) after outlier removal. Compared to waitlist or no-treatment, MBIs had significant small-to-large positive effects on global cognition ($g = 0.583$), executive attention ($g = 0.301$), WM accuracy ($g = 0.326$), inhibition accuracy ($g = 0.643$), shifting accuracy ($g = 0.272$), sustained attention accuracy ($g = 0.367$), and subjective cognitive functioning ($g = 0.257$). However, MBIs (vs. waitlist or no-treatment) did not affect orienting, WM latency, inhibition latency, shifting latency, intra-individual coefficient of variation, processing speed, verbal fluency, episodic memory, or cognitive error.

Pre-follow-up effect on global cognition. MBIs (vs. controls) had a significant and robust pre-follow-up treatment effect on global cognition, with a large effect size ($g = 0.808$).

Publication Bias Analyses for MBIs versus Waitlist/ No Treatment

***p*-uniform test.** Based on *p*-uniform tests, no publication bias was observed for all cognitive subdomains examined from pre- to post-treatment and pre- to follow-up (*p*-uniform values=-2.69–0.00, *p*=.571–.997).

Funnel plots. Visual inspection of all funnel plots showed no asymmetry indicative of publication bias.

Moderator Analyses for MBIs versus Waitlist/ No Treatment

Table S3 displays moderator analyses for MBIs vs. active control effect for global cognition, WM accuracy and latency, inhibition accuracy, processing speed, and cognitive error domains that showed significant effect size heterogeneity.

Age. Older (vs. younger) individuals evidenced smaller effects of MBIs (vs. no-treatment) on WM accuracy ($g = -0.502$). However, age did not significantly moderate the treatment effect for global cognition, WM latency, inhibition accuracy, inhibition latency, processing speed, and cognitive error.

Percentage female. More females led to a significantly weaker effect of MBIs (vs. waitlist or no-treatment) on processing speed ($g = -3.122$). However, the percentage of females was not a significant moderator of the MBI effect on global cognition, WM accuracy, WM latency, inhibition latency, and cognitive error.

Study quality. Higher study quality led to a significantly stronger effect of MBIs (vs. waitlist or no-treatment) on processing speed ($g = 1.936$). However, study quality did not significantly moderate MBIs' impact on global cognition, WM accuracy, WM latency, inhibition accuracy, inhibition latency, and cognitive error.

Number of sessions. Number of sessions was not a significant MBI moderator for global cognition, WM accuracy, WM latency, inhibition accuracy, inhibition latency, processing speed, and cognitive error.

Treatment duration. Longer treatment duration (total number of hours) was not a significant moderator of the impact of MBIs (vs. no-treatment) on global cognition, WM accuracy, WM latency, inhibition accuracy and latency, processing speed, and cognitive error.

Retention percentage. Retention percentage did not significantly moderate the impact of MBIs (vs. waitlist or no-treatment) on global cognition, WM accuracy, WM latency, inhibition accuracy, inhibition latency, processing speed, and cognitive error.

Completer analysis. Completer (vs. ITT) analysis yielded a significantly stronger effect of MBIs (vs. waitlist or no-treatment) for global cognition ($g = 0.619$ vs. 0.478) and WM accuracy ($g = 0.365$ vs. 0.000886). ITT (vs. completer) analysis generated a significantly larger effect on inhibition accuracy ($g = 0.804$ vs. 0.556). However, we could not determine if completer analysis moderated the MBI effect for WM latency, processing speed, and cognitive error as $k=1$ for ITT analysis.

Type of MBI. Standard MBSR or MBCT (vs. other non-standard MBI) had significantly stronger treatment effects for global cognition ($g = 0.796$ vs. 0.468), WM accuracy ($g = 0.404$ vs. 0.246), inhibition accuracy ($g = 1.213$ vs. 0.467), and cognitive error ($g = 0.412$ vs. 0.031) but not WM latency. Also, we could not test if MBI type moderated the treatment effect for processing speed as $k=1$ for standard MBI.

Treatment delivery. Self-guided MBI apps had a statistically significantly stronger treatment effect size than face-to-face MBIs for global cognition ($g = 0.588$ vs. 0.583), but the effect size difference was too small to be clinically significant. We could not examine if

treatment delivery mode moderated the effect of MBIs (vs. waitlist or no-treatment) on WM accuracy, WM latency, inhibition accuracy, processing speed, and cognitive error as $k=1$ for studies that used self-guided MBIs.

Clinical status. MBIs (vs. no-treatment or waitlist) had a significantly larger treatment effect for persons with (vs. without) elevated psychiatric symptoms concerning global cognition (PSY: $g = 0.822$; MED: $g = 0.618$; HC: $g = 0.345$), WM accuracy (PSY: $g = 0.396$; MED: $g = -0.251$; HC: $g = 0.301$), inhibition accuracy (PSY: $g = 0.974$; HC: $g = 0.300$), and cognitive errors (PSY: $g = 0.557$; HC: $g = 0.040$). However, we could not determine if clinical status moderated treatment effect for processing speed and WM latency as $k=1$ for samples with a clinical diagnosis.

Risk-of-Bias for MBIs versus No Treatment/ Waitlist

Figure 3 presents the risk-of-bias plots for the effect of MBIs compared to no treatment or waitlist on cognitive functions. No RCTs included in this meta-analysis had high randomization bias. Some concerns emerged for 10.91% of the studies due to deviations from the intended intervention due to the trial context, but none showed a high risk of bias. There were concerns due to missing outcome data in 21.82% of the studies, as they did not report the degree of missing data or if appropriate steps such as multiple imputation or other reasonable data replacement strategies (e.g., full information maximum likelihood) were taken. However, no studies showed a high risk of bias due to missing data. In addition, some concerns emerged in 3.64% of the studies wherein assessors were aware of the participant's treatment allocation, but the remaining 96.36% of studies had a low risk of bias. Concerning selection bias risk, one study (1.82%) had a high bias, 10.91% of studies showed some concerns, but the remaining 87.27% had a low risk of bias.

Comparison of Significant Treatment Effect Sizes for MBIs versus No Treatment/Waitlist

Table S5 in the Supplementary Materials compares all MBI (vs. no-treatment or waitlist) effects on various cognitive functioning domains tested herein. These significant treatment effect sizes were not statistically significantly different from one another (Fisher's r -to- z comparison statistics=-0.470 to 0.435, p =.638 to .998).

Effect of MBIs Compared to Active Control

Effect size heterogeneity. Significant moderate-to-large effect size heterogeneity was observed for global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning. However, no significant effect size heterogeneity was found for orienting, executive attention, WM accuracy, WM latency, inhibition accuracy, shifting accuracy, shifting latency, intra-individual coefficient of variation, processing speed, verbal fluency, episodic memory, and cognitive error (Table 3).

Cognitive outcome effect sizes. MBIs vs. active controls had significant effects on global cognition ($g = 0.208$), executive attention ($g = 0.192$), WM accuracy ($g = 0.296$), inhibition accuracy ($g = 0.192$), shifting accuracy ($g = 0.200$), sustained attention accuracy ($g = 0.212$), intra-individual coefficient of variation ($g = 0.337$), and subjective cognitive functioning ($g = 0.394$), with small-to-moderate effect sizes. However, MBIs (vs. active controls) had no significant impact on orienting, WM latency, inhibition latency, shifting latency, processing speed, verbal fluency, episodic memory, and cognitive error (Table 3 and Figure 4).

Pre-follow-up effect on global cognition. There was a significant pre-follow-up effect of MBIs (vs. active controls) on global cognition, with a small effect size ($g = 0.231$).

Publication Bias Analyses for MBIs versus Active Control

***p*-uniform test.** The *p*-uniform tests found no publication bias for all cognitive subdomains inspected from pre- to post-treatment and pre- to follow-up (*p*-uniform values=2.60-0.85, *p*=.283-.996).

Funnel plots. Visual inspection of all funnel plots showed no asymmetry suggesting publication bias.

Moderator Analyses for MBIs versus Active Control

Table S4 displays moderator analyses for MBIs vs. active control effect for global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning domains that showed significant effect size heterogeneity.

Age. Age did not significantly moderate MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning.

Percentage of females. Percentage of females did not significantly moderate the effect of MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning.

Study quality. Study quality did not significantly moderate MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning.

Number of sessions. Number of sessions did not significantly moderate the effect of MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning.

Treatment duration. Treatment duration (total number of hours spent in treatment) did not significantly moderate the effect of MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning.

Retention percentage. Retention percentage did not significantly moderate MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning.

Completer analysis. Completer (vs. ITT) analysis had a significantly smaller effect of MBIs (vs. active controls) on global cognition ($g = 0.207$ vs. 0.211), subjective cognitive functioning ($g = 0.405$ vs. 0.393), and sustained attention accuracy ($g = 0.221$ vs. 0.0672). We could not test completer analysis moderation for inhibition latency as $k=1$ for ITT analysis.

Type of MBI. Non-standard MBIs had significantly stronger effects (vs. standard MBSR or MBCT) compared to active control for global cognition ($g = 0.229$ vs. 0.171), sustained attention accuracy ($g = 0.112$ vs. -0.149), and subjective cognitive functioning ($g = 0.475$ vs. 0.276). We could not determine MBI type moderation for inhibition latency because $k=1$ for standard MBI.

Treatment delivery. Face-to-face MBIs had significantly larger treatment effects than self-guided MBIs for global cognition ($g = 0.228$ vs. 0.121), sustained attention accuracy ($g = 0.115$ vs. -0.00438), and subjective cognitive functioning ($g = 0.413$ vs. 0.312). There was no treatment moderator effect of delivery mode on inhibition latency.

Clinical status. The effect of MBIs (vs. active control) on global cognition was significantly stronger for persons with elevated psychiatric symptoms and healthy controls than those with heightened medical symptoms (PSY: $g = 0.211$; HC: $g = 0.222$; MED: $g = 0.130$). Further, the impact of MBIs (vs. active control) on sustained attention accuracy was significantly stronger for persons with elevated psychiatric symptoms than healthy controls and those with heightened medical symptoms (PSY: $g = 0.201$; MED: $g = -0.0922$; HC: $g = 0.0911$). For subjective cognitive functioning as the outcome, MBI (vs. active control) effects was

significantly larger for persons with heightened medical and psychiatric symptoms than healthy controls (MED: $g = 0.447$; PSY: $g = 0.307$; HC: $g = 0.436$). We could not determine the moderation effect for inhibition latency as $k=1$ for persons with a clinical diagnosis.

Risk-of-Bias for MBIs versus Active Controls

Figure 5 presents risk-of-bias plots for studies examining MBIs vs. active control. No studies (0%) showed a risk of randomization bias. Some concerns emerged for 19.72% of the studies regarding bias due to deviations from intended interventions, but none showed a high risk of bias. Some missing data bias concerns were identified for 24.66% of the studies, but none showed high risk of bias. Some measurement bias concerns arose for 9.59% of studies, but none showed high risk of bias. Some selection bias concerns were present for 12.33% of studies, but none had a high risk of bias.

Comparison of Significant Treatment Effect Sizes for MBIs versus Active Controls

Table S6 compares all MBI (vs. active control) effects on various cognitive functioning domains examined herein. All treatment effect sizes did not significantly vary from one another (Fisher's r -to- z comparison statistics=-0.204 to 0.182, $p=.839$ to 1.000).

Discussion

Overall Effects of MBIs on Global Cognition and 15 Cognitive Subdomains

Building on prior work, this novel meta-analysis of 111 RCTs observed that MBI packages had small-to-moderate positive impacts on some but not all cognitive subdomains after controlling for reported treatment fidelity in all primary effect size analyses. Specifically, MBIs had small-to-moderate effects on global cognition, executive attention, WM accuracy, inhibition accuracy, shifting accuracy, sustained attention, and subjective cognitive functioning. This was true when compared to no-treatment and waitlist (Figure 2; average $g = 0.249$ – 0.644) and active

controls (Figure 4; average $g = 0.192\text{--}0.394$). Results are concordant with the general observation that active-controlled trials demonstrate weaker effects than waitlist-controlled trials (e.g., Cillessen et al., 2019), likely because active controls also benefited cognitive improvement to some degree. Moreover, we observed zero publication bias based on the p -uniform test and funnel plots, thus offering confidence in the validity of our findings and inferences drawn on how MBIs impact cognitive functioning, as detailed below.

A noteworthy finding was how MBIs impacted global cognition and six cognitive subdomains irrespective of the comparator. Extending the meta-analysis of Whitfield et al. (2022), such results imply that in these domains, MBI-delivered skills were more potent than those imparted by active controls. However, as MBIs did not consistently affect nine out of 15 subdomains and significant effect sizes were small in the other domains, researchers and clinicians should exercise caution concerning MBIs' beneficial effects on these domains. Other researchers have drawn similar conclusions (e.g., Noone & Hogan, 2018; Van Dam et al., 2018). Our findings were similar to other meta-analytic reports of the small yet substantial positive impact of MBIs on global cognition and these six cognitive subdomains (Cásedas et al., 2020; Dunning et al., 2019; Han, 2021; Im et al., 2021; Lao et al., 2016; Mak et al., 2018; Sanchez-Lara et al., 2021; Verhaeghen, 2021; Whitfield et al., 2022; Yakobi et al., 2021). At the same time, we built on these prior meta-analytic reports by testing far more cognitive subdomains as outcomes and adjusted for treatment fidelity in all analyses. Furthermore, we comprehensively tested more potential moderators (effect modifiers) in evaluating the effects of MBIs on cognitive functioning.

Noteworthy is that significant maintenance of treatment gain on global cognition was observed from pre-treatment to follow-up, with small-to-moderate effect sizes ($g = 0.583$ when

compared to waitlist or no-treatment, and $g = 0.208$ relative to active control). The effect of MBIs on global cognition might be mainly attributable to significant effects on specific cognitive subdomains (i.e., executive attention, WM accuracy, inhibition accuracy, shifting accuracy, sustained attention, and subjective cognitive functioning). This possibility is based on evidence that substantial correlations exist between global cognition and these cognitive subdomains (Biagianti et al., 2019; Coors et al., 2022).

Relatedly, the finding that MBIs' impact on global cognition extended across time, in addition to evidence showing that MBIs had post-treatment effects that impacted cognition beyond attention measures (i.e., global cognition, executive attention, WM, inhibition accuracy, shifting accuracy), bolsters propositions that MBIs yield long-term persistent effects (Malinowski & Shalamanova, 2017), and lead to generalization of skills to tasks, objects, or contents beyond the ones practiced. Moreover, results that treatment effect sizes did not substantially differ between measures of attentional control and EF ($g = -0.028$ – 0.643) versus other cognitive subdomains ($g = 0.070$ – 0.976) provide more evidence for such viewpoints. Collectively, the topic of the benefit of MBIs on specific cognitive functioning subdomains over extended periods deserves more investigation. Our current meta-analysis was only well-powered to examine global cognition at follow-up, but not other unique cognitive subdomains.

Mixed Effects of MBIs

Attentional Control Constructs. Findings that MBIs improved sustained attention accuracy concur with theories positing that MBIs boost unwavering focus on intended tasks and non-judgmental acceptance as time progresses (Bishop et al., 2004). They also highlight the importance of assessing multiple sustained attention indices (e.g., accuracy, intra-individual coefficient of variation, etc.) to evaluate theories of how MBIs enhance attentional stability. Note

that the intra-individual coefficient of variation was the only new cognitive subdomain that MBIs significantly positively impacted when transiting from comparing no-treatment/waitlist to comparing active controls. This finding may be explained by the fact that studies with active control (vs. no-treatment) comparators had higher study quality and slightly lower number of sessions (refer to Table S2 for more information on differences between studies with no-treatment and active controls). Moreover, our findings were consistent with a recent review which showed that meditation practices enhanced accuracy instead of latency-based indices of attentional control components over time (Sumantry & Stewart, 2021).

Intriguingly, MBIs improved executive attention but did not improve orienting aspects of attentional control. These findings lend credence to recent formulations (Prakash et al., 2020) that argue for the *specificity* of the effects of MBIs on attentional control facets. Theories that executive attention is intrinsic to various kinds of practices that MBIs promote by reducing mind wandering, attentional lapses, and attentional allocation away from emotional and non-emotional distractions (Good et al., 2015; Hölzel et al., 2011; Lin et al., 2019; Vago & Silbersweig, 2012) could account for these findings. Conversely, null treatment effects on orienting might be partly due to the “decentered” stance that MBIs teach (Bishop et al., 2004) and how MBIs tend to cultivate balance of awareness to internal stimuli and external events without necessarily instructing selective attention toward a specific set of objects (Sumantry & Stewart, 2021; Verhaeghen, 2021). One potential implication of these findings may be that a long-term commitment to mindfulness practices spanning years to decades (i.e., longer than the average length of MBIs herein; Isbel & Mahar, 2015; Lodha & Gupta, 2022) or other intervention modalities (e.g., gamified cognitive training; Green & Bavelier, 2003) are necessary to enhance the orienting subdomain. These potential accounts require precise empirical testing.

EF Constructs. Relatedly, MBIs had no significant effects on WM, inhibition, shifting latencies, and processing speed relative to all control groups. This pattern was inconsistent with observations that MBIs can facilitate swifter responses on general cognitive and EF-timed tasks (Jang et al., 2018). Overall, our results suggest that MBIs impacted cognitive processing *effectiveness* (captured by accuracy) more than efficiency (measured by latency) and offer only partial support for the viewpoint that MBIs promote both aspects of cognitive function (Raffone & Srinivasan, 2017). Lack of impact on efficiency may be due to the serene and non-striving features of mindfulness practices, which may be less likely to increase any sense of time pressure.

Non-Significant Effects: Episodic Memory, Verbal Fluency, & Cognitive Error

Also, MBIs had no main effects on episodic memory, verbal fluency, and cognitive error, irrespective of the treatment comparator. Results support hypotheses of null relations between trait mindfulness and declarative/episodic memory relative to other forms of memory (e.g., specificity of emotionally-laden or personally-salient autobiographical memories; Levi & Rosenstreich, 2019; Whitfield et al., 2022). Our nonsignificant findings for episodic memory and verbal fluency also support hypotheses that MBIs likely do not assist with the storage and recall phases of verbal learning (Lueke & Lueke, 2019; Whitfield et al., 2022). Conversely, our results are discrepant from a recent qualitative review showing a beneficial effect of MBIs on verbal fluency (Hazlett-Stevens et al., 2019); however, that review focused on older adults, and verbal fluency was assessed solely with the controlled oral word association test.

Moderators

Number of Sessions and Treatment Duration. Noteworthy is the few heterogeneous treatment effects that emerged. For example, the number of sessions and treatment duration were

not significant treatment moderators, suggesting no support for the dose-response treatment effects hypothesis (Chiesa et al., 2011). Our null dose-response effects replicated evidence in recent quantitative reviews (Im et al., 2021; Verhaeghen, 2021). Such results are encouraging concerning the clinical utility of brief MBIs to alleviate distress and enhance cognitive functioning (Schumer et al., 2018).

Study Quality. Higher study quality dovetailed with a more significant effect of MBIs (vs. no-treatment) on processing speed. This result concurs with a prior meta-analytic finding that study quality positively moderated the impact of MBIs on negative affect and various health issues (Schumer et al., 2018). Among the studies that examined the effect of MBIs on processing speed, those with worse (vs. better) study quality did not provide information about whether baseline sociodemographics variables differed between treatment groups (e.g., Rothschild et al., 2017) and had baseline processing speed scores that were marginally significantly lower in the treatment than control group (e.g., Lacerda et al., 2018). These factors might partly account for study quality increasing the positive effect of MBIs (vs. no-treatment) on processing speed. More broadly, however, study quality did not change the impact of MBIs (vs. no-treatment) on global cognition, WM accuracy and latency, inhibition accuracy and latency, and cognitive error. Further, study quality did not moderate MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning. Overall, this pattern of results means that except for processing speed, study quality likely did not moderate the strength of treatment effects on most cognitive functioning outcomes.

Socio-demographics. Regarding sample attribute treatment moderators, older age was related to a *weaker* effect of MBIs (vs. no-treatment) on WM accuracy. Such finding parallels meta-analytic data showing that CBT was less efficacious for more senior (vs. younger) adults

with generalized anxiety disorder (Kishita & Laidlaw, 2017). Results may be explained by the fact that WM accuracy tends to decline with age, and sustained, deliberate practice is required to maintain MBI-derived gains in WM accuracy (Greenberg et al., 2019; Jha et al., 2019; Whitfield et al., 2022). Clearly, these speculations merit further scrutiny. Nonetheless, the fact that age did not moderate the effects of MBIs on global cognition, WM latency, inhibition accuracy and latency, processing speed, cognitive error, sustained attention accuracy, and subjective cognitive functioning aligns with theories that argue MBIs can benefit cognitive functioning to an equal degree for adults at various developmental stages (e.g., Berk et al., 2017).

Also, the higher percentage of females was related to smaller impact of MBIs (vs. no-treatment) on processing speed. This might be partly because women tend to outperform men on processing speed tasks involving letters and numbers (Malagoli & Usai, 2018; Roivainen, 2011), representing the bulk of measures used by RCTs and thus having less room for improvement. Future MBI RCTs can examine this hypothesis. Also, gender did not moderate the effect of MBIs (vs. no-treatment) on global cognition, WM accuracy and latency, inhibition accuracy and latency, and cognitive error. Further, gender did not moderate the impact of MBIs (vs. active controls) on global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning. These nonsignificant gender moderator effects support the idea that MBIs likely positively influence males and females equally (Katz & Toner, 2013).

Clinical Status. Of note, MBIs (vs. no-treatment) generally had larger impacts on global cognition, inhibition accuracy, WM accuracy, and cognitive error for persons with (vs. without) elevated psychiatric symptoms compared to those with heightened medical symptoms and healthy controls. Findings might be because neurocognitive deficits are common in psychiatric populations (Abramovitch et al., 2021). They are also concordant with meta-analytic data

showing that brief MBIs alleviated negative affect and mental health symptoms more strongly in psychiatric samples than healthy controls (Schumer et al., 2018). Plausibly, psychiatric populations are more motivated to engage in MBI strategies and have more room to improve these domain-specific cognitive abilities. More severe problems and variations in cognitive functioning deficits among patients with psychiatric issues relative to physical illnesses (Baune et al., 2009) could also account for these outcomes. Subsequent studies can evaluate these conjectures.

Simultaneously, MBIs (vs. active controls) had more prominent effects on global cognition and sustained attention accuracy for those with elevated psychiatric symptoms and healthy controls than persons with heightened medical symptoms. However, the impact of MBIs (vs. active controls) on subjective cognitive functioning was more substantial for persons with heightened medical symptoms, followed by healthy controls and then those with elevated psychiatric symptoms. It is unclear why we found these contradictory results. One possibility is that these results were linked to the fact that there were fewer sessions overall in the studies that included active (vs. no-treatment) controls. Perhaps healthy controls were more likely to benefit than clinical samples in response to shorter treatment lengths. Another testable account might relate to evidence that the correlation between negative affective symptoms and the tendency to describe thoughts and emotions mindfully was the strongest in medical samples (Carpenter et al., 2019). In addition, the fact that medical samples often have higher distress levels than healthy controls (Hodges et al., 2005) and physical illness stressors could motivate mindfulness practices and related healthy behaviors, which promote subjective cognitive functioning (Sala et al., 2020), could explain these findings.

Treatment Delivery. The slightly stronger effect of self-guided (vs. face-to-face) MBIs when compared to waitlist or no treatment on global cognition although statistically significant, was not clinically meaningful. This observation concurred with previous meta-analytic evidence that level of guidance from a therapist or digital mental health intervention coach might not moderate the intervention effect on mental health symptoms (Dworschak et al., 2022). However, such null moderation effects of treatment delivery tend to be the exception and the more common finding in the MBI literature is that face-to-face is more efficacious than self-guided (Thompson et al., 2021). Consistent with this more common finding, there were more potent effects for face-to-face MBIs (vs. active controls) than app- or Internet-delivered self-guided MBIs on global cognition, sustained attention accuracy, and subjective cognitive functioning, but not inhibition latency. This pattern may be due to greater accountability and motivation with therapeutic support of face-to-face MBIs, concordant with literature on MBIs targeting a reduction in depression, anxiety, and related mental health symptoms (Berle et al., 2015; French et al., 2017; Goslar et al., 2017; Lauricella, 2013; Spijkerman et al., 2016). Future work should examine if and how the added benefits of the instructor-led format are sufficiently substantial to outweigh the gains of self-guided MBIs (e.g., higher scalability, reduced costs, etc.).

Type of MBI. Another moderator finding was that standard MBSR and MBCT (vs. non-standard MBIs) generally showed more significant effects (vs. no-treatment or waitlist) for global cognition, WM accuracy, inhibition accuracy, and cognitive error, but not WM latency. In contradiction, however, *non-standard MBIs* (vs. standard MBSR or MBCT) had more substantial effects on global cognition, sustained attention accuracy, and subjective cognitive functioning when active controls were the comparator. In examining studies that compared a non-standard MBI to active control, such studies were more likely to contain treatments tailored to specific

populations they intended to treat (e.g., military cohorts; Jha et al., 2019) than studies comparing non-standard MBIs to no-treatment. Strategically adapting protocols to suit the needs of the target population might yield greater treatment effects than standard MBIs.

Study Limitations and Strengths

Study limitations should be considered. First, as with all meta-analyses, there were variations in the delivery of MBI protocols that could not be accounted for (Cuijpers et al., 2008). We also found significant heterogeneity, as indicated by the Q statistic for six cognitive functioning domains (global cognition, WM accuracy, WM latency, inhibition accuracy, processing speed, and cognitive error) compared to no-treatment. Likewise, a significant Q statistic was observed for four domains (global cognition, inhibition latency, sustained attention accuracy, and subjective cognitive functioning) compared to active controls. Large irregularities in treatment structure and content are endemic in the mindfulness literature (Van Dam et al., 2018; Whitfield et al., 2022), and our meta-analysis was not immune from such flaws. Future MBI RCTs should pay more attention to and measure the degree to which treatment protocols were executed with precision to strengthen internal validity (via standardization of treatment implementation), construct validity, and replicability of findings (Moncher & Prinz, 1991). Such efforts can further clarify the *facets* of treatment fidelity (e.g., integrity, differentiation, adherence) that moderate impact (Crane & Hecht, 2018; Moncher & Prinz, 1991). There is ample room for growth concerning the methodological quality of included studies (average scores ranging from 3.69 to 5.67 out of 6.00). Relatedly, bias linked to missing outcome data pertains to the fact that many MBI RCTs did not use the gold standard ITT analysis (i.e., 32.1% compared with waitlist/no-treatment and 44.0% with active controls). Completer analyses likely inflated and biased effect sizes (McCoy, 2017). Future MBI RCTs can improve their

methodology by using ITT analyses to obtain a more accurate account. Moreover, the current meta-analysis cannot disambiguate the effects of specific MBIs techniques as we are only aware of one dismantling study using cognitive outcomes (Britton et al., 2018).

Future efforts to isolate specific MBI skills or *components* within an RCT (Stein & Witkiewitz, 2020) with dismantling studies and network meta-analyses (Furukawa et al., 2021) are necessary to understand better how MBIs enhance certain cognitive functions. As a recent meta-analysis showed that stand-alone MBIs (e.g., body scans, focusing on sounds, mindful sitting, slowed diaphragmatic breathing, etc.) could yield comparable small-to-moderate benefits on psychological symptoms compared to manualized MBI packages (Blanck et al., 2018), future studies could test if such a pattern would extend to cognitive functioning. Moreover, future work could advance the field by testing if *unique* mindfulness techniques induced more potent effects than others (e.g., FA vs. OM) on separate subdomains of cognitive function (e.g., Britton et al., 2018).

Other shortcomings pertain to sample characteristics. Restriction of age range was observed when testing MBIs on orienting (ages 8-50). Investigations could clarify if treatment effects specifically for orienting extend to older age groups. Also, 63% of studies did not report ethnicity breakdown. Virtually no studies reported the sexual orientation/gender identity of their sample, a severe shortcoming of the current literature (Heck et al., 2017). Recruiting middle-class, White females with tertiary education and above was a typical pattern (Mars & Abbey, 2010). It is essential to test MBIs' impact on diverse populations, as MBIs produced differential (e.g., weaker) outcomes for older adults (Goldberg et al., 2021), children (Dunning et al., 2019), persons of color, and low-income individuals (Sun et al., 2022). Upcoming investigations are

thus encouraged to include such information for the field to reduce health disparities concerning the positive effects of MBIs on cognitive functioning.

Limitations notwithstanding, our meta-analysis has several strengths. We prevented file-drawer effects by searching, identifying, and including five unpublished doctoral and master theses and grey literature (e.g., preprints) (Lipsey & Wilson, 2001). Further, our dataset allowed us to test if age, percentage of females, study quality, number of treatment sessions, retention percentage, completer analysis (vs. ITT), MBI type (standard MBSR or MBCT vs. non-standard MBI), treatment delivery mode (face-to-face vs. self-guided), clinical status, and presence of reported fidelity checks, moderated treatment effects. In addition, this meta-analysis can catalyze future work on individual differences and treatment adaptations by synthesizing effect sizes to determine the impact of MBIs on various cognitive subdomains.

Conclusions

To conclude, data pooled across 111 MBI RCTs in the current, up-to-date meta-analysis suggested that MBIs benefitted global cognition and six cognitive subdomains (regardless of the control group and after adjusting for presence of fidelity checks). In particular, for executive attention, inhibition accuracy, WM accuracy, shifting accuracy, sustained attention accuracy, and subjective cognitive functioning, MBIs yielded small-to-moderate yet clinically meaningful effect sizes. However, MBIs did not positively affect orienting, WM latency, inhibition latency, shifting latency, processing speed, verbal fluency, episodic memory, and cognitive error. The positive effect on intra-individual coefficient of variation was substantial only when active control was the comparator. Overall, MBIs benefitted EF and sustained attention accuracy-based rather than latency-based outcomes, likely because mindfulness practices promote calmness in ways that emphasize the here-and-now or attaining goals effectively over getting tasks done

efficiently (Hoge et al., 2021). Plausibly, improvements in EF and sustained attention accuracy indices might contribute to why MBIs improve mood regulation (e.g., reduced repetitive thinking; Gu et al., 2015) and physical immunity (e.g., lowered inflammation; Dunn & Dimolareva, 2022). In addition, the finding that MBIs enhanced subjective cognitive functioning might be one of the mechanisms by which MBIs improve flexible thinking and perspective-taking (Mediavilla et al., 2021).

Our meta-analysis also built on previous ones by determining more extensively how various potential moderators might modify the effect of MBIs on global cognition and 15 cognitive subdomains. Few significant moderator results emerged. Although the impact of MBIs on these cognitive outcomes was broadly similar across age and gender, MBIs had weaker effects on WM accuracy for older than younger adults and processing speed for females than males. Psychiatric and medical samples versus healthy controls generally benefitted more from MBIs to target global cognition, some accuracy-based indices (inhibition, WM, sustained attention), and subjective cognitive functioning. Also, the absence of dose-response effects bodes well for the prospect of brief and scalable MBIs (e.g., Zainal & Newman, 2023) to enhance global cognition and the abovementioned six cognitive domains. At the same time, compared to self-guided MBIs, instructor-led face-to-face MBIs yielded more considerable impact on global cognition, sustained attention accuracy, and subjective cognitive functioning, highlighting the value of delivery by a qualified practitioner. Finally, standard MBIs, such as MBCT and MBSR, were better than non-standard MBIs in targeting mostly EF indices (WM and inhibition accuracy and cognitive error), likely due to their rigor. However, non-standard MBIs that tended to be highly tailored to specific target populations were better than standard MBIs in improving sustained attention accuracy and subjective cognitive functioning.

References

- Abbott, R. A., Whear, R., Rodgers, L. R., Bethel, A., Thompson Coon, J., Kuyken, W., . . . Dickens, C. (2014). Effectiveness of mindfulness-based stress reduction and mindfulness based cognitive therapy in vascular disease: A systematic review and meta-analysis of randomised controlled trials. *Journal of Psychosomatic Research*, 76(5), 341-351.
<https://doi.org/10.1016/j.jpsychores.2014.02.012>
- Abramovitch, A., Short, T., & Schweiger, A. (2021). The C Factor: Cognitive dysfunction as a transdiagnostic dimension in psychopathology. *Clinical Psychology Review*, 86, 102007.
<https://doi.org/10.1016/j.cpr.2021.102007>
- Achenbach, T. (1991). *Manual for the child behavior Checklist/4-18 and 1991 profile*. University of Vermont Department of Psychiatry.
- Achenbach, T. M., & McConaughy, S. H. (2003). The Achenbach System of empirically based assessment. In C. R. Reynolds & R. W. Kamphaus (Eds.), *Handbook of psychological and educational assessment of children: Personality, behaviour, and context* (pp. 406–430). Guilford Press.
- Achenbach, T. M., & Rescorla, L. A. (2001). *Manual for the ASEBA school-age forms & profiles*. University of Vermont, Research Center for Children, Youth, and Families.
- Allen, T. A., & Fortin, N. J. (2013). The evolution of episodic memory. *Proceedings of the National Academy of Sciences*, 110(Suppl. 2), 10379-10386.
<https://doi.org/10.1073/pnas.1301199110>
- Anālayo, B. (2019a). Meditation on the breath: Mindfulness and focused attention. *Mindfulness*, 10(8), 1684-1691. <https://doi.org/10.1007/s12671-019-01169-9>

- Anālayo, B. (2019b). Open monitoring and mindfulness. *Mindfulness*, 10(7), 1437-1442.
<https://doi.org/10.1007/s12671-019-01181-z>
- Anderson, N. D., Lau, M. A., Segal, Z. V., & Bishop, S. R. (2007). Mindfulness-based stress reduction and attentional control. *Clinical Psychology & Psychotherapy*, 14(6), 449-463.
<https://doi.org/10.1002/cpp.544>
- Army Individual Test Battery. (1944). *Manual of directions and scoring*. War Department, Adjutant General's Office.
- Aschenbrenner, A., Tucha, O., & Lange, K. W. (2001). *RWT Regensburger Wortflüssigkeits-Test, Handanweisung*. Hogrefe.
- Atkins, A. S., Berman, M. G., Reuter-Lorenz, P. A., Lewis, R. L., & Jonides, J. (2011). Resolving semantic and proactive interference in memory over the short-term. *Memory & Cognition*, 39(5), 806-817. <https://doi.org/10.3758/s13421-011-0072-5>
- Awh, E., Belopolsky, A. V., & Theeuwes, J. (2012). Top-down versus bottom-up attentional control: a failed theoretical dichotomy. *Trends in Cognitive Sciences*, 16(8), 437-443.
<https://doi.org/10.1016/j.tics.2012.06.010>
- Babcock, H., & Levy, L. (1940). *The measurement of efficiency of mental functioning (revised examination): Test and manual of directions*. C. H. Stoelting.
- Baer, R. A., Smith, G. T., & Allen, K. B. (2004). Assessment of mindfulness by self-report: the Kentucky inventory of mindfulness skills. *Assessment*, 11(3), 191-206.
<https://doi.org/10.1177/1073191104268029>
- Bastian, M., & Sackur, J. (2013). Mind wandering at the fingertips: Automatic parsing of subjective states based on response time variability. *Frontiers in Psychology*, 4, 573.
<https://doi.org/10.3389/fpsyg.2013.00573>

- Baune, B. T., McAfoose, J., Leach, G., Quirk, F., & Mitchell, D. (2009). Impact of psychiatric and medical comorbidity on cognitive function in depression. In *Psychiatry and Clinical Neurosciences* (2009/07/02 ed., Vol. 63, pp. 392-400).
- Bellgrove, M. A., Hester, R., & Garavan, H. (2004). The functional neuroanatomical correlates of response variability: Evidence from a response inhibition task. *Neuropsychologia*, 42(14), 1910-1916. <https://doi.org/10.1016/j.neuropsychologia.2004.05.007>
- Benedict, R. H. B., Schretlen, D., Groninger, L., & Brandt, J. (1998). Hopkins Verbal Learning Test – Revised: Normative data and analysis of inter-form and test-retest reliability. *Clinical Neuropsychologist*, 12(1), 43-55. <https://doi.org/10.1076/clin.12.1.43.1726>
- Benton, A., & Hampsher, K. (1978). *Multilingual aphasia examination*. University of Iowa.
- Berg, E. A. (1948). A simple objective technique for measuring flexibility in thinking. *Journal of General Psychology*, 39(1), 15-22. <https://doi.org/10.1080/00221309.1948.9918159>
- Berk, L., van Boxtel, M., & van Os, J. (2017). Can mindfulness-based interventions influence cognitive functioning in older adults? A review and considerations for future research. *Aging & Mental Health*, 21(11), 1113-1120. <https://doi.org/10.1080/13607863.2016.1247423>
- Berle, D., Starcevic, V., Milicevic, D., Hannan, A., Dale, E., Brakoulis, V., & Viswasam, K. (2015). Do patients prefer face-to-face or internet-based therapy? *Psychotherapy and Psychosomatics*, 84(1), 61-62. <https://doi.org/10.1159/000367944>
- Biagianti, B., Fisher, M., Brandrett, B., Schlosser, D., Loewy, R., Nahum, M., & Vinogradov, S. (2019). Development and testing of a web-based battery to remotely assess cognitive health in individuals with schizophrenia. *Schizophrenia Research*, 208, 250-257. <https://doi.org/10.1016/j.schres.2019.01.047>

- Biederman, I., Glass, A. L., & Stacy, E. W., Jr. (1973). Searching for objects in real-world scenes. *J Exp Psychol*, 97(1), 22-27. <https://doi.org/10.1037/h0033776>
- Biederman, I., Mezzanotte, R. J., & Rabinowitz, J. C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology*, 14(2), 143-177. [https://doi.org/https://doi.org/10.1016/0010-0285\(82\)90007-X](https://doi.org/https://doi.org/10.1016/0010-0285(82)90007-X)
- Bishop, S. R., Lau, M., Shapiro, S., Carlson, L., Anderson, N. D., Carmody, J., . . . Devins, G. (2004). Mindfulness: a proposed operational definition. *Clinical Psychology: Science and Practice*, 11(3), 230-241. <https://doi.org/10.1093/clipsy.bph077>
- Black, D. S., & Slavich, G. M. (2016). Mindfulness meditation and the immune system: A systematic review of randomized controlled trials. *Annals of the New York Academy of Sciences*, 1373(1), 13-24. <https://doi.org/10.1111/nyas.12998>
- Blanck, P., Perleth, S., Heidenreich, T., Kröger, P., Ditzen, B., Bents, H., & Mander, J. (2018). Effects of mindfulness exercises as stand-alone intervention on symptoms of anxiety and depression: Systematic review and meta-analysis. *Behaviour Research and Therapy*, 102, 25-35. <https://doi.org/10.1016/j.brat.2017.12.002>
- Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). Fixed-effect model. In M. Borenstein, L. V. Hedges, J. P. T. Higgins, & H. R. Rothstein (Eds.), *Introduction to meta-analysis* (pp. 63-68). John Wiley & Sons, Ltd.
- Braver, T. S. (2012). The variable nature of cognitive control: A dual mechanisms framework. *Trends in Cognitive Sciences*, 16(2), 106-113. <https://doi.org/10.1016/j.tics.2011.12.010>
- Brickenkamp, R. (2002). *Afmerksamkeits-Belastungs-Test (Test d2) [The D2 Test of Attention]* (9th ed.). Hogrefe.

- Brickenkamp, R., Schmidt-Atzert, L., & Liepmann, D. (2010). *d2-R – Test d2 – Revision (Aufmerksamkeits- und Konzentrationstest)*. Tests Info. Hogrefe.
- Brickenkamp, R., & Zillmer, E. (1998). *The D2 test of attention*. Hogrefe & Huber.
- Britton, W. B., Davis, J. H., Loucks, E. B., Peterson, B., Cullen, B. H., Reuter, L., . . . Lindahl, J. R. (2018). Dismantling mindfulness-based cognitive therapy: Creation and validation of 8-week focused attention and open monitoring interventions within a 3-armed randomized controlled trial. *Behaviour Research and Therapy*, 101, 92-107.
<https://doi.org/10.1016/j.brat.2017.09.010>
- Broadbent, D. E., Cooper, P. F., FitzGerald, P., & Parkes, K. R. (1982). The Cognitive Failures Questionnaire (CFQ) and its correlates. *British Journal of Clinical Psychology*, 21(1), 1-16. <https://doi.org/10.1111/j.2044-8260.1982.tb01421.x>
- Brown, K. W., Goodman, R. J., Ryan, R. M., & Anālayo, B. (2016). Mindfulness enhances episodic memory performance: Evidence from a multimethod investigation. *PLoS ONE*, 11(4), e0153309. <https://doi.org/10.1371/journal.pone.0153309>
- Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: inhibition, switching, and working memory. *Developmental Neuropsychology*, 19(3), 273-293. https://doi.org/10.1207/S15326942DN1903_3
- Burgess, P. W., Alderman, N., Evans, J., Emslie, H., & Wilson, B. A. (1998). The ecological validity of tests of executive function. *Journal of the International Neuropsychological Society*, 4(6), 547-558. <https://doi.org/10.1017/s1355617798466037>
- Burgess, P. W., Alderman, N., Forbes, C., Costello, A., Coates, L. M., Dawson, D. R., . . . Channon, S. (2006). The case for the development and use of "ecologically valid" measures of executive function in experimental and clinical neuropsychology. *Journal of*

the International Neuropsychological Society, 12(2), 194-209.

<https://doi.org/10.1017/S1355617706060310>

Cabrera, S., Edelstein, K., Mason, W. P., & Tartaglia, M. C. (2016). Assessing behavioral syndromes in patients with brain tumors using the frontal systems behavior scale (FrSBe). *Neuro-Oncology Practice*, 3(2), 113-119. <https://doi.org/10.1093/nop/npv055>

Cambráia, S. V. (2003). *Teste AC—Manual*. Brazil.

Cameron Ponitz, C. E., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly*, 23(2), 141-158. <https://doi.org/10.1016/j.ecresq.2007.01.004>

Carlson, S. M., & Zelazo, P. D. (2014). *Minnesota Executive Function Scale. Manual and Technical Report*. Reflection Sciences, Inc.

Carpenter, J. K., Conroy, K., Gomez, A. F., Curren, L. C., & Hofmann, S. G. (2019). The relationship between trait mindfulness and affective symptoms: A meta-analysis of the Five Facet Mindfulness Questionnaire (FFMQ). *Clinical Psychology Review*, 74, 101785. <https://doi.org/10.1016/j.cpr.2019.101785>

Cásedas, L., Pirruccio, V., Vadillo, M. A., & Lupiáñez, J. (2020). Does mindfulness meditation training enhance executive control? A systematic review and meta-analysis of randomized controlled trials in adults. *Mindfulness*, 11(2), 411-424. <https://doi.org/10.1007/s12671-019-01279-4>

Cheyne, J. A., Carriere, J. S., Solman, G. J., & Smilek, D. (2011). Challenge and error: Critical events and attention-related errors. *Cognition*, 121(3), 437-446. <https://doi.org/10.1016/j.cognition.2011.07.010>

- Cheyne, J. A., Carriere, J. S. A., & Smilek, D. (2006). Absent-mindedness: Lapses of conscious awareness and everyday cognitive failures. *Consciousness and Cognition*, 15(3), 578-592. <https://doi.org/10.1016/j.concog.2005.11.009>
- 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>
- Chiu, H. L., Chan, P. T., Kao, C. C., Chu, H., Chang, P. C., Hsiao, S. S., . . . Chou, K. R. (2018). Effectiveness of executive function training on mental set shifting, working memory and inhibition in healthy older adults: A double-blind randomized controlled trials. *Journal of Advanced Nursing*, 74(5), 1099-1113. <https://doi.org/10.1111/jan.13519>
- Cillessen, L., Johannsen, M., Speckens, A. E. M., & Zachariae, R. (2019). Mindfulness-based interventions for psychological and physical health outcomes in cancer patients and survivors: A systematic review and meta-analysis of randomized controlled trials. *Psycho-oncology*, 28(12), 2257-2269. <https://doi.org/10.1002/pon.5214>
- Cimprich, B., Visovatti, M., & Ronis, D. L. (2011). The Attentional Function Index—a self-report cognitive measure. *Psycho-Oncology*, 20(2), 194-202. <https://doi.org/10.1002/pon.1729>
- Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics*, 10(1), 101-129. <https://doi.org/10.2307/3001666>
- Coors, A., Breteler, M. M. B., & Ettinger, U. (2022). Processing speed, but not working memory or global cognition, is associated with pupil diameter during fixation. *Psychophysiology*, 59(11), e14089. <https://doi.org/10.1111/psyp.14089>

- Corbett, B. A., Constantine, L. J., Hendren, R., Rocke, D., & Ozonoff, S. (2009). Examining executive functioning in children with autism spectrum disorder, attention deficit hyperactivity disorder and typical development. *Psychiatry Res*, 166(2-3), 210-222. <https://doi.org/10.1016/j.psychres.2008.02.005>
- Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, 3(3), 201-215. <https://doi.org/10.1038/nrn755>
- Coughlan, A. K., & Hollows, S. E. (1985). *The adult memory and information processing battery (AMIPB) test manual*. Publication A. K. Coughlan, St James University Hospital, Leeds.
- Coull, J. T., & Nobre, A. C. (1998). Where and when to pay attention: The neural systems for directing attention to spatial locations and to time intervals as revealed by both PET and fMRI. *The Journal of Neuroscience*, 18(18), 7426-7435. <https://doi.org/10.1523/jneurosci.18-18-07426.1998>
- Crane, R. S., & Hecht, F. M. (2018). Intervention integrity in mindfulness-based research. *Mindfulness (N Y)*, 9(5), 1370-1380. <https://doi.org/10.1007/s12671-018-0886-3>
- Creswell, J. D. (2017). Mindfulness interventions. *Annual Review of Psychology*, 68(1), 491-516. <https://doi.org/10.1146/annurev-psych-042716-051139>
- Crook, T. H., Feher, E. P., & Larrabee, G. J. (1992). Assessment of memory complaint in age-associated memory impairment: The MAC-Q. *International Psychogeriatrics*, 4(2), 165-176. <https://doi.org/10.1017/S1041610292000991>
- Cubillo, A., Hermes, H., Berger, E., Winkel, K., Schunk, D., Fehr, E., & Hare, T. A. (2023). Intra-individual variability in task performance after cognitive training is associated with long-term outcomes in children. *Developmental Science*, 26(1), e13252. <https://doi.org/10.1111/desc.13252>

- Cuijpers, P., van Straten, A., Andersson, G., & van Oppen, P. (2008). Psychotherapy for depression in adults: A meta-analysis of comparative outcome studies. *Journal of consulting and clinical psychology*, 76(6), 909-922. <https://doi.org/10.1037/a0013075>
- Culbertson, W. C., & Zillmer, E. A. (1998). The Tower of LondonDX: A standardized approach to assessing executive functioning in children. *Archives of Clinical Neuropsychology*, 13(3), 285-301. [https://doi.org/10.1016/S0887-6177\(97\)00033-4](https://doi.org/10.1016/S0887-6177(97)00033-4)
- Daglas-Georgiou, R., Bryce, S., Smith, G., Kaur, M., Cheng, N., De Rozario, M., . . . Allott, K. (2022). Treatments for objective and subjective cognitive functioning in young people with depression: Systematic review of current evidence. *Early Intervention in Psychiatry*, 16(10), 1057-1074. <https://doi.org/10.1111/eip.13248>
- Dai, M., Li, Y., Gan, S., & Du, F. (2019). The reliability of estimating visual working memory capacity. *Scientific Reports*, 9(1), 1155. <https://doi.org/10.1038/s41598-019-39044-1>
- Dale, G., & Arnell, K. M. (2013). How reliable is the attentional blink? Examining the relationships within and between attentional blink tasks over time. *Psychological Research*, 77(2), 99-105. <https://doi.org/10.1007/s00426-011-0403-y>
- Delis, D. C., Kaplan, E., & Kramer, J. H. (2001). *The Delis–Kaplan executive function system: Examiner’s manual*. The Psychological Corporation.
- Delis, D. C., Kramer, J. H., Kaplan, E., & Ober, B. A. (2017). *California Verbal Learning Test-3* (3rd ed.). The Psychological Corporation.
- Derryberry, D., & Reed, M. A. (2002). Anxiety-related attentional biases and their regulation by attentional control. *Journal of Abnormal Psychology*, 111(2), 225-236. <https://doi.org/10.1037/0021-843X.111.2.225>

- Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science*, 318(5855), 1387-1388.
<https://doi.org/10.1126/science.1151148>
- Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do". *Developmental Psychobiology*, 29(4), 315-334. [https://doi.org/10.1002/\(SICI\)1098-2302\(199605\)29:4<315::AID-DEV2>3.0.CO;2-T](https://doi.org/10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T)
- Dickinson, J., Friary, P., & McCann, C. M. (2016). The influence of mindfulness meditation on communication and anxiety: A case study of a person with aphasia. *Aphasiology*, 31(9), 1044-1058. <https://doi.org/10.1080/02687038.2016.1234582>
- Diehl, M., Semegon, A. B., & Schwarzer, R. (2006). Assessing attention control in goal pursuit: A component of dispositional self-regulation. *Journal of Personality Assessment*, 86(3), 306-317. https://doi.org/10.1207/s15327752jpa8603_06
- Dierckx, E., Engelborghs, S., De Raedt, R., De Deyn, P. P., D'Haenens, E., Verte, D., & Ponjaert-Kristoffersen, I. (2011). The 10-word learning task in the differential diagnosis of early Alzheimer's disease and elderly depression: A cross-sectional pilot study. *Aging and Mental Health*, 15(1), 113-121. <https://doi.org/10.1080/13607863.2010.505228>
- Dixon, R. A., Hultsch, D. F., & Hertzog, C. (1988). The Metamemory in Adulthood (MIA) questionnaire. *Psychopharmacology Bulletin*, 24(4), 671-688.
- Dockree, P. M., Bellgrove, M. A., O'Keeffe, F. M., Moloney, P., Aimola, L., Carton, S., & Robertson, I. H. (2006). Sustained attention in traumatic brain injury (TBI) and healthy controls: Enhanced sensitivity with dual-task load. *Experimental Brain Research*, 168(1), 218-229. <https://doi.org/10.1007/s00221-005-0079-x>

- Dunn, T. J., & Dimolareva, M. (2022). The effect of mindfulness-based interventions on immunity-related biomarkers: A comprehensive meta-analysis of randomised controlled trials. *Clinical Psychology Review*, 92, 102124. <https://doi.org/10.1016/j.cpr.2022.102124>
- Dunning, D. L., Griffiths, K., Kuyken, W., Crane, C., Foulkes, L., Parker, J., & Dalgleish, T. (2019). Research review: The effects of mindfulness-based interventions on cognition and mental health in children and adolescents – a meta-analysis of randomized controlled trials. *Journal of Child Psychology and Psychiatry*, 60(3), 244-258. <https://doi.org/10.1111/jcpp.12980>
- Durlak, J. A. (2009). How to select, calculate, and interpret effect sizes. *Journal of Pediatric Psychology*, 34(9), 917-928. <https://doi.org/10.1093/jpepsy/jsp004>
- Dworschak, C., Heim, E., & Maercker, A. (2022). Efficacy of internet-based interventions for common mental disorder symptoms and psychosocial problems in older adults: A systematic review and meta-analysis. *Internet Interventions*, 27, 100498. <https://doi.org/10.1016/j.invent.2022.100498>
- Eberth, J., & Sedlmeier, P. (2012). The effects of mindfulness meditation: A meta-analysis. *Mindfulness*, 3(3), 174-189. <https://doi.org/10.1007/s12671-012-0101-x>
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, 16(1), 143-149. <https://doi.org/10.3758/BF03203267>
- Esposito, E. (2015). Neural correlates of mindfulness and executive function training in internationally adopted children: A randomized, controlled trial. Retrieved from the University of Minnesota Digital Conservancy,

https://conservancy.umn.edu/bitstream/handle/11299/182262/Esposito_umn_0130E_16161.pdf?sequence=1&isAllowed=y.

- Esterman, M., & Rothlein, D. (2019). Models of sustained attention. *Current Opinion in Psychology*, 29, 174-180. <https://doi.org/10.1016/j.copsyc.2019.03.005>
- Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, 14(3), 340-347. <https://doi.org/10.1162/089892902317361886>
- Fernando, A. T., Skinner, K., & Consedine, N. S. (2016). Increasing compassion in medical decision-making: Can a brief mindfulness intervention help? *Mindfulness*, 8(2), 276-285. <https://doi.org/10.1007/s12671-016-0598-5>
- Fetterman, A. K., & Robinson, M. D. (2011). Routine cognitive errors: A trait-like predictor of individual differences in anxiety and distress. *Cognition and Emotion*, 25(2), 244-264. <https://doi.org/10.1080/02699931.2010.486941>
- Fisher, G. G., Chacon, M., & Chaffee, D. S. (2019). Theories of cognitive aging and work. In *Work Across the Lifespan* (pp. 17-45). <https://doi.org/10.1016/b978-0-12-812756-8.00002-5>
- Fisher, Z., Tipton, E., & Zhipeng, H. (2017). *robumeta: Robust variance meta-regression*.
- Flanagan, D. P., & Kaufman, A. S. (2009). Introduction and overview. In A. S. Kaufman & N. L. Kaufman (Eds.), *Essentials of WISC-IV assessment* (2nd ed., pp. 2–51). John Wiley and Sons, Inc.
- Flook, L., Goldberg, S. B., Pinger, L., & Davidson, R. J. (2015). Promoting prosocial behavior and self-regulatory skills in preschool children through a mindfulness-based kindness curriculum. *Developmental Psychology*, 51(1), 44-51. <https://doi.org/10.1037/a0038256>

- Flook, L., Smalley, S. L., Kitil, M. J., Galla, B. M., Kaiser-Greenland, S., Locke, J., . . . Kasari, C. (2010). Effects of mindful awareness practices on executive functions in elementary school children. *Journal of Applied School Psychology, 26*(1), 70-95.
<https://doi.org/10.1080/15377900903379125>
- Flynn, M. J., Abolhosseini, S., Gamboa, J., Campbell, T. S., & Carlson, L. E. (2023). Mindfulness-based interventions and cognitive function in cancer survivors: A systematic review and meta-analysis. *Journal of Psychosocial Oncology Research & Practice, 5*(1).
<https://doi.org/10.1097/or9.0000000000000094>
- Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). "Mini-mental state". A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*(3), 189-198. [https://doi.org/10.1016/0022-3956\(75\)90026-6](https://doi.org/10.1016/0022-3956(75)90026-6)
- French, K., Golijani-Moghaddam, N., & Schröder, T. (2017). What is the evidence for the efficacy of self-help acceptance and commitment therapy? A systematic review and meta-analysis. *Journal of Contextual Behavioral Science, 6*(4), 360-374.
<https://doi.org/10.1016/j.jcbs.2017.08.002>
- Furukawa, T. A., Suganuma, A., Ostinelli, E. G., Andersson, G., Beevers, C. G., Shumake, J., . . . Cuijpers, P. (2021). Dismantling, optimising, and personalising internet cognitive behavioural therapy for depression: A systematic review and component network meta-analysis using individual participant data. *The Lancet Psychiatry, 8*(6), 500-511.
[https://doi.org/10.1016/s2215-0366\(21\)00077-8](https://doi.org/10.1016/s2215-0366(21)00077-8)
- 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>

Gamer, M., Lemon, J., Fellows, I., & Singh, P. (2007). *IRR: various coefficients of interrater reliability and agreement*. In

Garland, E. L., Farb, N. A., Goldin, P., & Fredrickson, B. L. (2015). Mindfulness broadens awareness and builds eudaimonic meaning: A process model of mindful positive emotion regulation. *Psychological Inquiry*, 26(4), 293-314.

<https://doi.org/10.1080/1047840X.2015.1064294>

Gill, L.-N., Renault, R., Campbell, E., Rainville, P., & Khoury, B. (2020). Mindfulness induction and cognition: A systematic review and meta-analysis. *Consciousness and Cognition*, 84, 102991. <https://doi.org/10.1016/j.concog.2020.102991>

Gioia, G. A., Isquith, P. K., Guy, S. C., & Kenworthy, L. (2000). *Behavior rating inventory of executive function*. Psychological Assessment Resources.

Goldberg, S. B., Riordan, K. M., Sun, S., & Davidson, R. J. (2021). The empirical status of mindfulness-based interventions: A systematic review of 44 meta-analyses of randomized controlled trials. *Perspectives on Psychological Science*, 17(1), 108-130.

<https://doi.org/10.1177/1745691620968771>

Good, D. J., Lyddy, C. J., Glomb, T. M., Bono, J. E., Brown, K. W., Duffy, M. K., . . . Lazar, S. W. (2015). Contemplating mindfulness at work. *Journal of Management*, 42(1), 114-142.

<https://doi.org/10.1177/0149206315617003>

Goslar, M., Leibetseder, M., Muench, H. M., Hofmann, S. G., & Laireiter, A. R. (2017). Efficacy of face-to-face versus self-guided treatments for disordered gambling: A meta-analysis. *Journal of Behavioral Addictions*, 6(2), 142-162.

<https://doi.org/10.1556/2006.6.2017.034>

Grace, J., & Malloy, P. (2001). *The Frontal Systems Behavior Scale: Professional manual*.

Psychological Assessment Resources.

Grant, D. A., & Berg, E. A. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *Journal of Experimental Psychology: General*, 38(4), 404-411. <https://doi.org/10.1037/h0059831>

Green, C. S., & Bavelier, D. (2003). Action video game modifies visual selective attention. *Nature*, 423(6939), 534-537. <https://doi.org/10.1038/nature01647>

Greenberg, J., Romero, V. L., Elkin-Frankston, S., Bezdek, M. A., Schumacher, E. H., & Lazar, S. W. (2019). Reduced interference in working memory following mindfulness training is associated with increases in hippocampal volume. *Brain Imaging and Behavior*, 13(2), 366-376. <https://doi.org/10.1007/s11682-018-9858-4>

Gu, J., Strauss, C., Bond, R., & Cavanagh, K. (2015). How do mindfulness-based cognitive therapy and mindfulness-based stress reduction improve mental health and wellbeing? A systematic review and meta-analysis of mediation studies. *Clinical Psychology Review*, 37, 1-12. <https://doi.org/10.1016/j.cpr.2015.01.006>

Gualtieri, C. T., & Johnson, L. G. (2006). Reliability and validity of a computerized neurocognitive test battery, CNS Vital Signs. *Archives of Clinical Neuropsychology*, 21(7), 623-643. <https://doi.org/10.1016/j.acn.2006.05.007>

Haigh, E. A. P., Moore, M. T., Kashdan, T. B., & Fresco, D. M. (2010). Examination of the factor structure and concurrent validity of the Langer mindfulness/mindlessness scale. *Assessment*, 18(1), 11-26. <https://doi.org/10.1177/1073191110386342>

Hallgren, K. A. (2012). Computing inter-rater reliability for observational data: an overview and tutorial. *Tutorials in quantitative methods for psychology*, 8(1), 23-34.

https://www.unboundmedicine.com/medline/citation/22833776/Computing_Inter_Rater_Reliability_for_Observational_Data:_An_Overview_and_Tutorial

<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC22833776/>

Hallion, L. S., Tolin, D. F., & Diefenbach, G. J. (2019). Enhanced cognitive control over task-irrelevant emotional distractors in generalized anxiety disorder versus obsessive-compulsive disorder. *Journal of Anxiety Disorders*, 64, 71-78.

<https://doi.org/10.1016/j.janxdis.2019.02.004>

Han, A. (2021). Effects of mindfulness-and acceptance-based interventions on quality of life, coping, cognition, and mindfulness of people with multiple sclerosis: A systematic review and meta-analysis. *Psychology, Health & Medicine*, 1-18.

<https://doi.org/10.1080/13548506.2021.1894345>

Hazlett-Stevens, H., Singer, J., & Chong, A. (2019). Mindfulness-based stress reduction and mindfulness-based cognitive therapy with older adults: A qualitative review of randomized controlled outcome research. *Clinical Gerontologist*, 42(4), 347-358.

<https://doi.org/10.1080/07317115.2018.1518282>

Heck, N. C., Mirabito, L. A., LeMaire, K., Livingston, N. A., & Flentje, A. (2017). Omitted data in randomized controlled trials for anxiety and depression: A systematic review of the inclusion of sexual orientation and gender identity. *Journal of consulting and clinical psychology*, 85(1), 72-76. <https://doi.org/10.1037/ccp0000123>

Hedge, C., Powell, G., & Sumner, P. (2018). The reliability paradox: Why robust cognitive tasks do not produce reliable individual differences. *Behavior Research Methods*, 50(3), 1166-1186. <https://doi.org/10.3758/s13428-017-0935-1>

- Henry, J. D., & Crawford, J. R. (2004). A meta-analytic review of verbal fluency performance following focal cortical lesions. *Neuropsychology*, 18(2), 284-295.
<https://doi.org/10.1037/0894-4105.18.2.284>
- Hester, R., Nandam, L. S., O'Connell, R. G., Wagner, J., Strudwick, M., Nathan, P. J., . . . Bellgrove, M. A. (2012). Neurochemical enhancement of conscious error awareness. *Journal of Neuroscience*, 32(8), 2619-2627. <https://doi.org/10.1523/JNEUROSCI.4052-11.2012>
- Higgins, J. P., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *British Medical Journal*, 327(7414), 557-560.
<https://doi.org/10.1136/bmj.327.7414.557>
- Higgins, J. P. T., Altman, D. G., Gøtzsche, P. C., Jüni, P., Moher, D., Oxman, A. D., . . . Sterne, J. A. C. (2011). The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *British Medical Journal*, 343, d5928.
<https://doi.org/10.1136/bmj.d5928>
- Higgins, J. P. T., & Green, S. (2011). *Cochrane Handbook for Systematic Reviews of Interventions Version 5.1.0*.
- Hodges, L. J., Humphris, G. M., & Macfarlane, G. (2005). A meta-analytic investigation of the relationship between the psychological distress of cancer patients and their carers. *Social Science & Medicine*, 60(1), 1-12. <https://doi.org/10.1016/j.socscimed.2004.04.018>
- Hoge, E. A., Acabchuk, R. L., Kimmel, H., Moitra, E., Britton, W. B., Dumais, T., . . . Fulwiler, C. (2021). Emotion-related constructs engaged by mindfulness-based interventions: A systematic review and meta-analysis. *Mindfulness*, 12(5), 1041-1062.
<https://doi.org/10.1007/s12671-020-01561-w>

Hogrefe. (2008). *Measuring intelligence with culture fair tests*. Hogrefe Ltd.

Hollingworth, A. (1998). Does consistent scene context facilitate object perception? *Journal of Experimental Psychology: General*, 127(4), 398-415. <https://doi.org/10.1037/0096-3445.127.4.398>

Hölzel, B. K., Lazar, S. W., Gard, T., Schuman-Olivier, Z., Vago, D. R., & Ott, U. (2011). How does mindfulness meditation work? Proposing mechanisms of action from a conceptual and neural perspective. *Perspectives on Psychological Science*, 6(6), 537-559. <https://doi.org/10.1177/1745691611419671>

Horner, M. D., Teichner, G., Kortte, K. B., & Harvey, R. T. (2002). Construct validity of the Babcock story recall test. *Applied Neuropsychology*, 9(2), 114-116. https://doi.org/10.1207/S15324826AN0902_7

Hsieh, S., Chang, C. C., & Meiran, N. (2012). Episodic retrieval and decaying inhibition in the competitor-rule suppression phenomenon. *Acta Psychologica*, 141(3), 316-321. <https://doi.org/10.1016/j.actpsy.2012.09.001>

Im, S., Stavas, J., Lee, J., Mir, Z., Hazlett-Stevens, H., & Caplovitz, G. (2021). Does mindfulness-based intervention improve cognitive function?: A meta-analysis of controlled studies. *Clinical Psychology Review*, 84, 101972. <https://doi.org/10.1016/j.cpr.2021.101972>

Isbel, B., & Mahar, D. (2015). Cognitive mechanisms of mindfulness: A test of current models. *Consciousness and Cognition*, 38, 50-59. <https://doi.org/10.1016/j.concog.2015.10.005>

Jang, J. H., Kim, J.-H., Yun, J.-Y., Choi, S.-H., An, S. C., & Kang, D.-H. (2018). Differences in functional connectivity of the insula between brain wave vibration in meditators and non-meditators. *Mindfulness*, 9(6), 1857-1866. <https://doi.org/10.1007/s12671-018-0928-x>

- Jersild, A. T. (1927). Mental set and shift. *Archives of Psychology*, 14, 89, 81-81.
- Jewsbury, P. A., Bowden, S. C., & Strauss, M. E. (2016). Integrating the switching, inhibition, and updating model of executive function with the Cattell-Horn-Carroll model. *Journal of Experimental Psychology: General*, 145(2), 220-245.
<https://doi.org/10.1037/xge0000119>
- Jha, A. P., Denkova, E., Zanesco, A. P., Witkin, J. E., Rooks, J., & Rogers, S. L. (2019). Does mindfulness training help working memory 'work' better? *Current Opinion in Psychology*, 28, 273-278. <https://doi.org/10.1016/j.copsyc.2019.02.012>
- Jha, A. P., Fabian, S. A., & Aguirre, G. K. (2004). The role of prefrontal cortex in resolving distractor interference. *Cognitive, Affective, & Behavioral Neuroscience*, 4(4), 517-527.
<https://doi.org/10.3758/cabn.4.4.517>
- Jha, A. P., & Kiyonaga, A. (2010). Working-memory-triggered dynamic adjustments in cognitive control. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 36(4), 1036-1042. <https://doi.org/10.1037/a0019337>
- Johnsen, T. J., & Friberg, O. (2015). The effects of cognitive behavioral therapy as an anti-depressive treatment is falling: A meta-analysis. *Psychological Bulletin*, 141(4), 747-768.
<https://doi.org/10.1037/bul0000015>
- Judah, M. R., Grant, D. M., Mills, A. C., & Lechner, W. V. (2014). Factor structure and validation of the Attentional Control Scale. *Cognition and Emotion*, 28(3), 433-451.
<https://doi.org/10.1080/02699931.2013.835254>
- Kane, M. J., Conway, A. R. A., Miura, T. K., & Colflesh, G. J. H. (2007). Working memory, attention control, and the N-back task: a question of construct validity. *Journal of*

Experimental Psychology: Learning, Memory, and Cognition, 33(3), 615-622.

<https://doi.org/10.1037/0278-7393.33.3.615>

Kaplan, E. F., Goodglass, H., & Weintraub, S. (1983). *The Boston Naming Test* (2nd ed.). Lea & Febiger.

Katz, D., & Toner, B. (2013). A systematic review of gender differences in the effectiveness of mindfulness-based treatments for substance use disorders. *Mindfulness*, 4(4), 318-331.

<https://doi.org/10.1007/s12671-012-0132-3>

Kaunhoven, R. J., & Dorjee, D. (2017). How does mindfulness modulate self-regulation in pre-adolescent children? An integrative neurocognitive review. *Neuroscience and Biobehavioral Reviews*, 74(Pt A), 163-184.

<https://doi.org/10.1016/j.neubiorev.2017.01.007>

Kazdin, A. E. (2017). *Research design in clinical psychology*. Pearson Education.

Kirk, U., Gu, X., Sharp, C., Hula, A., Fonagy, P., & Montague, P. R. (2016). Mindfulness training increases cooperative decision making in economic exchanges: Evidence from fMRI. *Neuroimage*, 138, 274-283. <https://doi.org/10.1016/j.neuroimage.2016.05.075>

Kishita, N., & Laidlaw, K. (2017). Cognitive behaviour therapy for generalized anxiety disorder: Is CBT equally efficacious in adults of working age and older adults? *Clinical Psychology Review*, 52, 124-136. <https://doi.org/10.1016/j.cpr.2017.01.003>

Psychology Review, 52, 124-136. <https://doi.org/10.1016/j.cpr.2017.01.003>

Koch, I., Gade, M., Schuch, S., & Philipp, A. M. (2010). The role of inhibition in task switching: A review. *Psychonomic Bulletin & Review*, 17(1), 1-14.

<https://doi.org/10.3758/PBR.17.1.1>

Korkmann, M., Kirk, U., & Kemp, S. (2007). *NEPSY-2* (2nd ed.). Psychological Corporation.

Kovács, F. (2013). *TLT: Manual*. Pyramid Productions.

Kramer, J. H., Mungas, D., Possin, K. L., Rankin, K. P., Boxer, A. L., Rosen, H. J., . . .

Widmeyer, M. (2014). NIH EXAMINER: Conceptualization and development of an executive function battery. *Journal of the International Neuropsychological Society*, 20(1), 11-19. <https://doi.org/10.1017/S1355617713001094>

Kueper, J. K., Speechley, M., & Montero-Odasso, M. (2018). The Alzheimer's Disease

Assessment Scale–Cognitive Subscale (ADAS-Cog): Modifications and responsiveness in pre-dementia populations. A narrative review. *Journal of Alzheimer's Disease*, 63(2), 423-444. <https://doi.org/10.3233/JAD-170991>

Lacerda, S. S., Little, S. W., & Kozasa, E. H. (2018). A stress reduction program adapted for the work environment: A randomized controlled trial with a follow-up. *Frontiers in Psychology*, 9(668). <https://doi.org/10.3389/fpsyg.2018.00668>

Lao, S.-A., Kissane, D., & Meadows, G. (2016). Cognitive effects of MBSR/MBCT: A systematic review of neuropsychological outcomes. *Consciousness and Cognition*, 45, 109-123. <https://doi.org/10.1016/j.concog.2016.08.017>

Lauricella, S. (2013). Mindfulness meditation with undergraduates in face-to-face and digital practice: A formative analysis. *Mindfulness*, 5(6), 682-688. <https://doi.org/10.1007/s12671-013-0222-x>

Lejuez, C. W., Read, J. P., Kahler, C. W., Richards, J. B., Ramsey, S. E., Stuart, G. L., . . .

Brown, R. A. (2002). Evaluation of a behavioral measure of risk taking: The Balloon Analogue Risk Task (BART). *Journal of Experimental Psychology: Applied*, 8(2), 75-84. <https://doi.org/10.1037//1076-898x.8.2.75>

Levi, U., & Rosenstreich, E. (2019). Mindfulness and memory: A review of findings and a potential model. *Journal of Cognitive Enhancement*, 3(3), 302-314.

<https://doi.org/10.1007/s41465-018-0099-7>

Levine, B., Stuss, D. T., Winocur, G., Binns, M. A., Fahy, L., Mandic, M., . . . Robertson, I. H. (2007). Cognitive rehabilitation in the elderly: Effects on strategic behavior in relation to goal management. *Journal of the International Neuropsychological Society*, 13(1), 143-

152. <https://doi.org/10.1017/S1355617707070178>

Lezak, M., Howieson, D., Bigler, E., & Tranel, D. (2012). *Neuropsychological assessment*. Oxford University Press.

Lin, Y., Fisher, M. E., & Moser, J. S. (2019). Clarifying the relationship between mindfulness and executive attention: A combined behavioral and neurophysiological study. *Social Cognitive and Affective Neuroscience*, 14(2), 205-215.

<https://doi.org/10.1093/scan/nsy113>

Lindsay, E. K., & Creswell, J. D. (2017). Mechanisms of mindfulness training: Monitor and acceptance theory (MAT). *Clinical Psychology Review*, 51, 48-59.

<https://doi.org/10.1016/j.cpr.2016.10.011>

Lipsey, M. W., & Wilson, D. B. (2001). *Applied social research methods series: Vol. 49. Practical meta-analysis*. Sage.

Lodha, S., & Gupta, R. (2022). Mindfulness, attentional networks, and executive functioning: A review of interventions and long-term meditation practice. *Journal of Cognitive Enhancement*, 6(4), 531-548. <https://doi.org/10.1007/s41465-022-00254-7>

- Lueke, A., & Lueke, N. (2019). Mindfulness improves verbal learning and memory through enhanced encoding. *Memory & Cognition*, 47(8), 1531-1545.
<https://doi.org/10.3758/s13421-019-00947-z>
- Lutz, A., Jha, A. P., Dunne, J. D., & Saron, C. D. (2015). Investigating the phenomenological matrix of mindfulness-related practices from a neurocognitive perspective. *American Psychologist*, 70(7), 632-658. <https://doi.org/10.1037/a0039585>
- MacKillop, J., Amlung, M. T., Few, L. R., Ray, L. A., Sweet, L. H., & Munafò, M. R. (2011). Delayed reward discounting and addictive behavior: a meta-analysis. *Psychopharmacology (Berl)*, 216(3), 305-321. <https://doi.org/10.1007/s00213-011-2229-0>
- MacLean, K. A., Aichele, S. R., Bridwell, D. A., Mangun, G. R., Wojculik, E., & Saron, C. D. (2009). Interactions between endogenous and exogenous attention during vigilance. *Attention, Perception, & Psychophysics*, 71(5), 1042-1058.
<https://doi.org/10.3758/APP.71.5.1042>
- MacLean, K. A., Ferrer, E., Aichele, S. R., Bridwell, D. A., Zanesco, A. P., Jacobs, T. L., . . . Saron, C. D. (2010). Intensive meditation training improves perceptual discrimination and sustained attention. *Psychological Science*, 21(6), 829-839.
<https://doi.org/10.1177/0956797610371339>
- Magnusdottir, B. B., Faiola, E., Harms, C., Sigurdsson, E., Ettinger, U., & Haraldsson, H. M. (2019). Cognitive measures and performance on the antisaccade eye movement task. *Journal of Cognition*, 2(1), 3. <https://doi.org/10.5334/joc.52>

- Mak, C., Whittingham, K., Cunnington, R., & Boyd, R. N. (2018). Efficacy of mindfulness-based interventions for attention and executive function in children and adolescents - A systematic review. *Mindfulness*, 9(1), 59-78. <https://doi.org/10.1007/s12671-017-0770-6>
- Malagoli, C., & Usai, M. C. (2018). The effects of gender and age on inhibition and working memory organization in 14-to 19-year-old adolescents and young adults. *Cognitive Development*, 45, 10-23. <https://doi.org/10.1016/j.cogdev.2017.10.005>
- Malinowski, P., & Shalamanova, L. (2017). Meditation and cognitive ageing: The role of mindfulness meditation in building cognitive reserve. *Journal of Cognitive Enhancement*, 1(2), 96-106. <https://doi.org/10.1007/s41465-017-0022-7>
- Manglani, H. R., Samimy, S., Schirda, B., Nicholas, J. A., & Prakash, R. S. (2020). Effects of 4-week mindfulness training versus adaptive cognitive training on processing speed and working memory in multiple sclerosis. *Neuropsychology*, 34(5), 591-604. <https://doi.org/10.1037/neu0000633>
- Manly, T., Hawkins, K., Evans, J., Woldt, K., & Robertson, I. H. (2002). Rehabilitation of executive function: Facilitation of effective goal management on complex tasks using periodic auditory alerts. *Neuropsychologia*, 40(3), 271-281. [https://doi.org/10.1016/s0028-3932\(01\)00094-x](https://doi.org/10.1016/s0028-3932(01)00094-x)
- Manly, T., Robertson, I. H., Anderson, V., & Nimmo-Smith, I. (1999). *TEA-Ch: The test of everyday attention for children manual*. Thames Valley Test Company.
- Mars, T. S., & Abbey, H. (2010). Mindfulness meditation practise as a healthcare intervention: A systematic review. *International Journal of Osteopathic Medicine*, 13(2), 56-66. <https://doi.org/10.1016/j.ijosm.2009.07.005>

Mayr, U., & Keele, S. W. (2000). Changing internal constraints on action: The role of backward inhibition. *Journal of Experimental Psychology: General*, 129(1), 4-26.

<https://doi.org/10.1037/0096-3445.129.1.4>

McCoy, C. E. (2017). Understanding the intention-to-treat principle in randomized controlled trials. *Western Journal of Emergency Medicine*, 18(6), 1075-1078.

<https://doi.org/10.5811/westjem.2017.8.35985>

Mediavilla, R., Munoz-Sanjose, A., Rodriguez-Vega, B., Lahera, G., Palao, A., Bayon, C., . . .

Bravo-Ortiz, M. F. (2021). People with psychosis improve affective social cognition and self-care after a mindfulness-based social cognition training program (SocialMIND).

Psychiatric Rehabilitation Journal, 44(4), 391-395. <https://doi.org/10.1037/prj0000466>

Meiran, N., Hsieh, S., & Dimov, E. (2010). Resolving task rule incongruence during task switching by competitor rule suppression. *Journal of Experimental Psychology:*

Learning, Memory, and Cognition, 36(4), 992-1002. <https://doi.org/10.1037/a0019761>

Meyerhoff, H. S., Papenmeier, F., & Huff, M. (2017). Studying visual attention using the multiple object tracking paradigm: A tutorial review. *Attention, Perception, &*

Psychophysics, 79(5), 1255-1274. <https://doi.org/10.3758/s13414-017-1338-1>

Millett, G., D'Amico, D., Amestoy, M. E., Gyspeerd, C., & Fiocco, A. J. (2021). Do group-based mindfulness meditation programs enhance executive functioning? A systematic review and meta-analysis of the evidence. *Consciousness and Cognition*, 95, 103195.

<https://doi.org/10.1016/j.concog.2021.103195>

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D.

(2000). The unity and diversity of executive functions and their contributions to complex

- “frontal lobe” tasks: A latent variable analysis. *Cognitive Psychology*, 41(1), 49–100.
<https://doi.org/10.1006/cogp.1999.0734>
- Moher, D., Liberati, A., Tetzlaff, J., Altman, D. G., & The, P. G. (2009). Preferred reporting items for systematic reviews and meta-analyses: The PRISMA statement. *PLOS Medicine*, 6(7), e1000097. <https://doi.org/10.1371/journal.pmed.1000097>
- Mohs, R. C., Knopman, D., Petersen, R. C., Ferris, S. H., Ernesto, C., Grundman, M., . . . Alzheimer's Disease Cooperative Study. (1997). Development of cognitive instruments for use in clinical trials of antidementia drugs: Additions to the Alzheimer's Disease Assessment Scale that broaden its scope. *Alzheimer Disease and Associated Disorders*, 11(Suppl. 2), S13-21. <https://doi.org/10.1097/00002093-199700112-00003>
- Moncher, F. J., & Prinz, R. J. (1991). Treatment fidelity in outcome studies. *Clinical Psychology Review*, 11(3), 247-266. [https://doi.org/10.1016/0272-7358\(91\)90103-2](https://doi.org/10.1016/0272-7358(91)90103-2)
- Montazeri, A., Harirchi, I., Vahdani, M., Khaleghi, F., Jarvandi, S., Ebrahimi, M., & Haji-Mahmoodi, M. (1999). The European Organization for Research and Treatment of Cancer Quality of Life Questionnaire (EORTC QLQ-C30): Translation and validation study of the Iranian version. *Supportive Care in Cancer*, 7(6), 400-406.
<https://doi.org/10.1007/s005200050300>
- Montgomery, C., Fisk, J. E., Newcombe, R., & Murphy, P. N. (2005). The differential effects of ecstasy/polydrug use on executive components: shifting, inhibition, updating and access to semantic memory. *Psychopharmacology*, 182(2), 262-276.
<https://doi.org/10.1007/s00213-005-0065-9>
- Morris, J. C. (1993). The Clinical Dementia Rating (CDR): Current version and scoring rules. *Neurology*, 43(11), 2412-2414. <https://doi.org/10.1212/wnl.43.11.2412-a>

- Morris, S. B., & DeShon, R. P. (2002). Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs. *Psychological Methods*, 7(1), 105-125. <https://doi.org/10.1037/1082-989X.7.1.105>
- Mrazek, A. J., Mrazek, M. D., Cherolini, C. M., Cloughesy, J. N., Cynman, D. J., Gougis, L. J., . . . Schooler, J. W. (2019). The future of mindfulness training is digital, and the future is now. *Current Opinion in Psychology*, 28, 81-86. <https://doi.org/10.1016/j.copsyc.2018.11.012>
- Muller, C., Otto, B., Sawitzki, V., Kanagalingam, P., Scherer, J. S., & Lindberg, S. (2021). Short breaks at school: effects of a physical activity and a mindfulness intervention on children's attention, reading comprehension, and self-esteem. *Trends in Neuroscience and Education*, 25, 100160. <https://doi.org/10.1016/j.tine.2021.100160>
- Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., . . . Chertkow, H. (2005). The Montreal cognitive assessment (MoCA): a brief screening tool for mild cognitive impairment. *Journal of the American Geriatrics Society*, 53(4), 695-699. <https://doi.org/10.1111/j.1532-5415.2005.53221.x>
- Nee, D. E., Jonides, J., & Berman, M. G. (2007). Neural mechanisms of proactive interference-resolution. *Neuroimage*, 38(4), 740-751. <https://doi.org/10.1016/j.neuroimage.2007.07.066>
- Noone, C., & Hogan, M. J. (2018). A randomised active-controlled trial to examine the effects of an online mindfulness intervention on executive control, critical thinking and key thinking dispositions in a university student sample. *BMC Psychology*, 6(1), 13. <https://doi.org/10.1186/s40359-018-0226-3>

- Owen, A. M., McMillan, K. M., Laird, A. R., & Bullmore, E. (2005). N-back working memory paradigm: A meta-analysis of normative functional neuroimaging studies. *Human Brain Mapping, 25*(1), 46-59. <https://doi.org/10.1002/hbm.20131>
- Owens, M., Koster, E. H., & Derakshan, N. (2012). Impaired filtering of irrelevant information in dysphoria: An ERP study. *Social Cognitive and Affective Neuroscience, 7*(7), 752-763. <https://doi.org/10.1093/scan/nsr050>
- Owens, M., Koster, E. H., & Derakshan, N. (2013). Improving attention control in dysphoria through cognitive training: Transfer effects on working memory capacity and filtering efficiency. *Psychophysiology, 50*(3), 297-307. <https://doi.org/10.1111/psyp.12010>
- Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience, 35*(1), 73-89. <https://doi.org/10.1146/annurev-neuro-062111-150525>
- Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58*(1), 1-23. <https://doi.org/10.1146/annurev.psych.58.110405.085516>
- Posner, M. I., Rothbart, M. K., & Tang, Y.-Y. (2015). Enhancing attention through training. *Current Opinion in Behavioral Sciences, 4*, 1-5. <https://doi.org/10.1016/j.cobeha.2014.12.008>
- Prakash, R. S., Fountain-Zaragoza, S., Kramer, A. F., Samimy, S., & Wegman, J. (2020). Mindfulness and attention: Current state-of-affairs and future considerations. *Journal of Cognitive Enhancement. https://doi.org/10.1007/s41465-019-00144-5*

- Prencipe, A., & Zelazo, P. D. (2005). Development of affective decision making for self and other: evidence for the integration of first- and third-person perspectives. *Psychol Sci*, 16(7), 501-505. <https://doi.org/10.1111/j.0956-7976.2005.01564.x>
- Pylyshyn, Z. W., & Storm, R. W. (1988). Tracking multiple independent targets: Evidence for a parallel tracking mechanism. *Spatial Vision*, 3(3), 179-197. <https://doi.org/10.1163/156856888x00122>
- Raffone, A., Marzetti, L., Del Gratta, C., Perrucci, M. G., Romani, G. L., & Pizzella, V. (2019). Chapter 9 - Toward a brain theory of meditation. In N. Srinivasan (Ed.), *Progress in Brain Research* (Vol. 244, pp. 207-232). Elsevier. <https://doi.org/10.1016/bs.pbr.2018.10.028>
- Raffone, A., & Srinivasan, N. (2017). Mindfulness and cognitive functions: Toward a unifying neurocognitive framework. *Mindfulness*, 8(1), 1-9. <https://doi.org/10.1007/s12671-016-0654-1>
- Randolph, C. (1998). *The Repeatable Battery for the Assessment of Neuropsychological Status*. Psychological Corporation.
- Raucher-Chéné, D., Achim, A. M., Kaladjian, A., & Besche-Richard, C. (2017). Verbal fluency in bipolar disorders: A systematic review and meta-analysis. *Journal of Affective Disorders*, 207, 359-366. <https://doi.org/10.1016/j.jad.2016.09.039>
- Reeves, B. C. (2008). Principles of research: Limitations of non-randomized studies. *Surgery*, 26(3), 120-124. <https://doi.org/10.1016/j.mpsur.2008.02.004>
- Regard, M., Strauss, E., & Knapp, P. (1982). Children's production on verbal and non-verbal fluency tasks. *Percept Mot Skills*, 55(3 Pt 1), 839-844. <https://doi.org/10.2466/pms.1982.55.3.839>

- Reitan, R., & Wolfson, D. (1993). *The Halstead–Reitan neuropsychological test battery: Theory and clinical interpretation*. Neuropsychology Press.
- Reitan, R. M. (1958). Validity of the Trail Making Test as an indicator of organic brain damage. *Perceptual and Motor Skills*, 8(7), 271-276. <https://doi.org/10.2466/PMS.8.7.271-276>
- Rey, A. (1941). L'examen psychologique dans les cas d'encéphalopathie traumatique. (Les problems.). [The psychological examination in cases of traumatic encepholopathy. Problems.]. *Archives de Psychologie*, 28, 215-285.
- Rey, A. (1964). *The clinical examination in psychology*. Presses Universitaires De France.
- Ristic, J., Wright, A., & Kingstone, A. (2007). Attentional control and reflexive orienting to gaze and arrow cues. *Psychonomic Bulletin & Review*, 14(5), 964-969. <https://doi.org/10.3758/BF03194129>
- Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). 'Oops!': Performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, 35(6), 747-758. [https://doi.org/10.1016/S0028-3932\(97\)00015-8](https://doi.org/10.1016/S0028-3932(97)00015-8)
- Robertson, I. H., Ward, T., Ridgeway, V., & Nimmo-Smith, I. (1996). The structure of normal human attention: The test of everyday attention. *Journal of the International Neuropsychological Society*, 2(6), 525-534. <https://doi.org/10.1017/S1355617700001697>
- Rogers, R. D., & Monsell, S. (1995). Costs of a predictable switch between simple cognitive tasks. *Journal of Experimental Psychology: General*, 124(2), 207-231. <https://doi.org/10.1037/0096-3445.124.2.207>

Roivainen, E. (2011). Gender differences in processing speed: A review of recent research.

Learning and Individual Differences, 21(2), 145-149.

<https://doi.org/10.1016/j.lindif.2010.11.021>

Rosen, W. G., Mohs, R. C., & Davis, K. L. (1984). A new rating scale for Alzheimer's disease.

American Journal of Psychiatry, 141(11), 1356-1364.

<https://doi.org/10.1176/ajp.141.11.1356>

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological*

Bulletin, 86(3), 638-641. <https://doi.org/10.1037/0033-2909.86.3.638>

Roth, R. M., Isquith, P. K., & Gioia, G. A. (2005). *Behavior Rating Inventory of Executive*

Function - Adult Version (BRIEF-A). Psychological Assessment Resources.

Rothschild, S., Kaplan, G., Golan, T., & Barak, Y. (2017). Mindfulness meditation in the Israel

Defense Forces: Effect on cognition and satisfaction with life—A randomized controlled trial. *European Journal of Integrative Medicine*, 10, 71-74.

<https://doi.org/10.1016/j.eujim.2017.01.010>

Sala, M., Rochefort, C., Lui, P. P., & Baldwin, A. S. (2020). Trait mindfulness and health

behaviours: A meta-analysis. *Health Psychology Review*, 14(3), 345-393.

<https://doi.org/10.1080/17437199.2019.1650290>

Sanchez-Lara, E., Lozano-Ruiz, A., Perez-Garcia, M., & Caracuel, A. (2021). Efficacy of

mindfulness-based interventions in cognitive function in the elderly people: a systematic review and meta-analysis. *Aging and Mental Health*, 1-11.

<https://doi.org/10.1080/13607863.2021.1976724>

- Schumer, M. C., Lindsay, E. K., & Creswell, J. D. (2018). Brief mindfulness training for negative affectivity: A systematic review and meta-analysis. *Journal of consulting and clinical psychology*, 86(7), 569-583. <https://doi.org/10.1037/ccp0000324>
- Seeley, W. W., Menon, V., Schatzberg, A. F., Keller, J., Glover, G. H., Kenna, H., . . . Greicius, M. D. (2007). Dissociable intrinsic connectivity networks for salience processing and executive control. *The Journal of Neuroscience*, 27(9), 2349. <https://doi.org/10.1523/jneurosci.5587-06.2007>
- Servan-Schreiber, D., Cohen, J. D., & Steingard, S. (1996). Schizophrenic deficits in the processing of context: A test of a theoretical model. *Archives of General Psychiatry*, 53(12), 1105-1112. <https://doi.org/10.1001/archpsyc.1996.01830120037008>
- Shallice, T., & Burgess, P. W. (1991). Deficits in strategy application following frontal lobe damage in man. *Brain*, 114 (Pt 2), 727-741. <https://doi.org/10.1093/brain/114.2.727>
- Shapiro, S. L., Jazaieri, H., & Goldin, P. R. (2012). Mindfulness-based stress reduction effects on moral reasoning and decision making. *The Journal of Positive Psychology*, 7(6), 504-515. <https://doi.org/10.1080/17439760.2012.723732>
- Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin*, 86(2), 420-428. <https://doi.org/10.1037/0033-2909.86.2.420>
- Smith, A. (1982). *Symbol digit modalities test*. Western Psychological Services.
- Solanto, M. V., Abikoff, H., Sonuga-Barke, E., Schachar, R., Logan, G. D., Wigal, T., . . . Turkel, E. (2001). The ecological validity of delay aversion and response inhibition as measures of impulsivity in AD/HD: A supplement to the NIMH multimodal treatment study of AD/HD. *Journal of Abnormal Child Psychology*, 29(3), 215-228. <https://doi.org/10.1023/A:1010329714819>

- Solso, R. L., & McCarthy, J. E. (1981). Prototype formation of faces: A case of pseudo-memory. *British Journal of Psychology*, 72(Nov), 499-503. <https://doi.org/10.1111/j.2044-8295.1981.tb01779.x>
- Sood, A., & Jones, D. T. (2013). On mind wandering, attention, brain networks, and meditation. *Explore*, 9(3), 136-141. <https://doi.org/10.1016/j.explore.2013.02.005>
- Sorensen, L., Osnes, B., Visted, E., Svendsen, J. L., Adolfsdottir, S., Binder, P. E., & Schanche, E. (2018). Dispositional mindfulness and attentional control: The specific association between the mindfulness facets of non-judgment and describing with flexibility of early operating orienting in conflict detection. *Frontiers in Psychology*, 9, 2359. <https://doi.org/10.3389/fpsyg.2018.02359>
- Spector, A., & Biederman, I. (1976). Mental set and mental shift revisited. *The American Journal of Psychology*, 89(4), 669-679. <https://doi.org/10.2307/1421465>
- Spijkerman, M. P. J., Pots, W. T. M., & Bohlmeijer, E. T. (2016). Effectiveness of online mindfulness-based interventions in improving mental health: A review and meta-analysis of randomised controlled trials. *Clinical Psychology Review*, 45, 102-114. <https://doi.org/10.1016/j.cpr.2016.03.009>
- Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers*, 31(1), 137-149. <https://doi.org/10.3758/BF03207704>
- Stein, E., & Witkiewitz, K. (2020). Dismantling mindfulness-based programs: A systematic review to identify active components of treatment. *Mindfulness*, 11(11), 2470-2485. <https://doi.org/10.1007/s12671-020-01444-0>

- Sternberg, S. (1975). Memory scanning: New findings and current controversies. *Quarterly Journal of Experimental Psychology*, 27(1), 1-32.
<https://doi.org/10.1080/14640747508400459>
- Stieben, J., Lewis, M. D., Granic, I., Zelazo, P. D., Segalowitz, S., & Pepler, D. (2007). Neurophysiological mechanisms of emotion regulation for subtypes of externalizing children. *Development and Psychopathology*, 19(2), 455-480.
<https://doi.org/10.1017/S0954579407070228>
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, 18(6), 643-662. <https://doi.org/10.1037/h0054651>
- Sumantry, D., & Stewart, K. E. (2021). Meditation, mindfulness, and attention: A meta-analysis. *Mindfulness*. <https://doi.org/10.1007/s12671-021-01593-w>
- Sun, S., Goldberg, S. B., Loucks, E. B., & Brewer, J. A. (2022). Mindfulness-based interventions among people of color: A systematic review and meta-analysis. *Psychotherapy Research*, 32(3), 277-290. <https://doi.org/10.1080/10503307.2021.1937369>
- Sunderland, A., Watts, K., Baddeley, A. D., & Harris, J. E. (1986). Subjective memory assessment and test performance in elderly adults. *Journal of Gerontology*, 41(3), 376-384. <https://doi.org/10.1093/geronj/41.3.376>
- Tanner-Smith, E. E., Tipton, E., & Polanin, J. R. (2016). Handling complex meta-analytic data structures using robust variance estimates: A tutorial in R. *Journal of Developmental and Life-Course Criminology*, 2(1), 85-112. <https://doi.org/10.1007/s40865-016-0026-5>
- Teper, R., Segal, Z. V., & Inzlicht, M. (2013). Inside the mindful mind: How mindfulness enhances emotion regulation through improvements in executive control. *Current*

Directions in Psychological Science, 22(6), 449-454.

<https://doi.org/10.1177/0963721413495869>

Thompson, E. M., Destree, L., Albertella, L., & Fontenelle, L. F. (2021). Internet-based acceptance and commitment therapy: A transdiagnostic systematic review and meta-analysis for mental health outcomes. *Behavior Therapy*, 52(2), 492-507.

<https://doi.org/10.1016/j.beth.2020.07.002>

Tombaugh, T. N. (2006). A comprehensive review of the paced auditory serial addition test (PASAT). *Archives of Clinical Neuropsychology*, 21(1), 53-76.

<https://doi.org/10.1016/j.acn.2005.07.006>

Troyer, A. K., & Rich, J. B. (2002). Psychometric properties of a new metamemory questionnaire for older adults. *The Journals of Gerontology: Series B*, 57(1), P19-P27.

<https://doi.org/10.1093/geronb/57.1.P19>

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology*, 53, 1-25. <https://doi.org/10.1146/annurev.psych.53.100901.135114>

Ullmann, R. K., Sleator, E. K., & Sprague, R. L. (1997). *ADD-H Comprehensive Teacher Rating Scale (ACTeRS)*. MetriTech, Inc.

Unsworth, N., Heitz, R. P., Schrock, J. C., & Engle, R. W. (2005). An automated version of the operation span task. *Behavior Research Methods*, 37(3), 498-505.

<https://doi.org/10.3758/BF03192720>

Uusberg, H., Uusberg, A., Talpsep, T., & Paaver, M. (2016). Mechanisms of mindfulness: The dynamics of affective adaptation during open monitoring. *Biological Psychology*, 118,

94-106. <https://doi.org/10.1016/j.biopsycho.2016.05.004>

- Vago, D., & Silbersweig, D. A. (2012). Self-awareness, self-regulation, and self-transcendence (S-ART): a framework for understanding the neurobiological mechanisms of mindfulness. *Frontiers in Human Neuroscience*, 6(296), 296.
<https://doi.org/10.3389/fnhum.2012.00296>
- Vago, D. R., Gupta, R. S., & Lazar, S. W. (2019). Measuring cognitive outcomes in mindfulness-based intervention research: a reflection on confounding factors and methodological limitations. *Current Opinion in Psychology*, 28, 143-150.
<https://doi.org/10.1016/j.copsyc.2018.12.015>
- Valls-Serrano, C., Verdejo-Garcia, A., & Caracul, A. (2016). Planning deficits in polysubstance dependent users: Differential associations with severity of drug use and intelligence. *Drug and Alcohol Dependence*, 162, 72-78.
<https://doi.org/10.1016/j.drugalcdep.2016.02.027>
- van Assen, M. A. L. M., van Aert, R. C. M., & Wicherts, J. M. (2015). Meta-analysis using effect size distributions of only statistically significant studies. *Psychological Methods*, 20(3), 293-309. <https://doi.org/10.1037/met0000025>
- Van Dam, N. T., van Vugt, M. K., Vago, D. R., Schmalzl, L., Saron, C. D., Olendzki, A., . . . Meyer, D. E. (2018). Mind the hype: A critical evaluation and prescriptive agenda for research on mindfulness and meditation. *Perspectives on Psychological Science*, 13(1), 36-61. <https://doi.org/10.1177/1745691617709589>
- van der Elst, W., van Boxtel, M. P., van Breukelen, G. J., & Jolles, J. (2006). The Letter Digit Substitution Test: normative data for 1,858 healthy participants aged 24-81 from the Maastricht Aging Study (MAAS): Influence of age, education, and sex. *Journal of*

Clinical and Experimental Neuropsychology, 28(6), 998-1009.

<https://doi.org/10.1080/13803390591004428>

van Leeuwen, S., Muller, N. G., & Melloni, L. (2009). Age effects on attentional blink performance in meditation. *Consciousness and Cognition*, 18(3), 593-599.

<https://doi.org/10.1016/j.concog.2009.05.001>

van Vugt, M. K., & Slagter, H. A. (2014). Control over experience? Magnitude of the attentional blink depends on meditative state. *Consciousness and Cognition*, 23, 32-39.

<https://doi.org/10.1016/j.concog.2013.11.001>

Vangkilde, S., Bundesen, C., & Coull, J. T. (2011). Prompt but inefficient: nicotine differentially modulates discrete components of attention. *Psychopharmacology*, 218(4), 667-680.

<https://doi.org/10.1007/s00213-011-2361-x>

Verhaeghen, P. (2021). Mindfulness as attention training: Meta-analyses on the links between attention performance and mindfulness interventions, long-term meditation practice, and trait mindfulness. *Mindfulness*, 12(3), 564-581. [https://doi.org/10.1007/s12671-020-](https://doi.org/10.1007/s12671-020-01532-1)

[01532-1](https://doi.org/10.1007/s12671-020-01532-1)

Verhagen, A. P., de Vet, H. C. W., de Bie, R. A., Kessels, A. G. H., Boers, M., Bouter, L. M., & Knipschild, P. G. (1998). The Delphi list: A criteria list for quality assessment of randomized clinical trials for conducting systematic reviews developed by Delphi consensus. *Journal of Clinical Epidemiology*, 51(12), 1235-1241.

[https://doi.org/10.1016/S0895-4356\(98\)00131-0](https://doi.org/10.1016/S0895-4356(98)00131-0)

Viechtbauer, W. (2010). metafor: Meta-Analysis Package for R. *R package version*, 2010, 1-0.

Viechtbauer, W., & Cheung, M. W.-L. (2010). Outlier and influence diagnostics for meta-analysis. *Research Synthesis Methods*, 1(2), 112-125. <https://doi.org/10.1002/jrsm.11>

- Vilgis, V., Silk, T. J., & Vance, A. (2015). Executive function and attention in children and adolescents with depressive disorders: A systematic review. *European Child & Adolescent Psychiatry*, 24(4), 365-384. <https://doi.org/10.1007/s00787-015-0675-7>
- Wechsler, D. (1991). *The Wechsler intelligence scale for children* (3rd ed.). Psychological Corporation.
- Wechsler, D. (2008). *Wechsler Adult Intelligence Scale-Fourth edition: Technical and interpretative manual*. Pearson Assessment.
- Wetherell, J. L., Hershey, T., Hickman, S., Tate, S. R., Dixon, D., Bower, E. S., & Lenze, E. J. (2017). Mindfulness-based stress reduction for older adults with stress disorders and neurocognitive difficulties: A randomized controlled trial. *Journal of Clinical Psychiatry*, 78(7), e734-e743. <https://doi.org/10.4088/JCP.16m10947>
- Whitfield, T., Barnhofer, T., Acabchuk, R., Cohen, A., Lee, M., Schlosser, M., . . . Marchant, N. L. (2022). The effect of mindfulness-based programs on cognitive function in adults: A systematic review and meta-analysis. *Neuropsychology Review*, 32(3), 677-702. <https://doi.org/10.1007/s11065-021-09519-y>
- Wickham, H. (2016). *ggplot2: Elegant Graphics for Data Analysis*. Springer-Verlag. <https://ggplot2.tidyverse.org>
- Wilson, B. A., Alderman, N., Burgess, P. W., Emslie, H., & Evans, J. J. (2003). Behavioural assessment of the dysexecutive syndrome (BADS). *Journal of Occupational Psychology, Employment and Disability*, 5(2), 33-37.
- Wimmer, L., Bellingrath, S., & von Stockhausen, L. (2016). Cognitive effects of mindfulness training: Results of a pilot study based on a theory driven approach. *Frontiers in Psychology*, 7, 1037-1037. <https://doi.org/10.3389/fpsyg.2016.01037>

- 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>
- Wright, A., & Diamond, A. (2014). An effect of inhibitory load in children while keeping working memory load constant. *Frontiers in Psychology*, 5, 213. <https://doi.org/10.3389/fpsyg.2014.00213>
- Yakobi, O., Smilek, D., & Danckert, J. (2021). The effects of mindfulness meditation on attention, executive control and working memory in healthy adults: A meta-analysis of randomized controlled trials. *Cognitive Therapy and Research*. <https://doi.org/10.1007/s10608-020-10177-2>
- Zainal, N. H., & Newman, M. G. (2023). A randomized controlled trial of a 14-day mindfulness ecological momentary intervention (MEMI) for generalized anxiety disorder. *European Psychiatry*, 66(1), e12. <https://doi.org/10.1192/j.eurpsy.2023.2>
- Zanesco, A. P., King, B. G., MacLean, K. A., Jacobs, T. L., Aichele, S. R., Wallace, B. A., . . . Saron, C. D. (2016). Meditation training influences mind wandering and mindless reading. *Psychology of Consciousness: Theory, Research, and Practice*, 3(1), 12-33. <https://doi.org/10.1037/cns0000082>
- Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). II. NIH toolbox cognition battery (CB): measuring executive function and attention. *Monographs of the Society for Research in Child Development*, 78(4), 16-33. <https://doi.org/10.1111/mono.12032>

Zoogman, S., Goldberg, S. B., Hoyt, W. T., & Miller, L. (2015). Mindfulness interventions with youth: A meta-analysis. *Mindfulness*, 6(2), 290-302. <https://doi.org/10.1007/s12671-013-0260-4>

Table 1

Definition of Unique Cognitive Functioning Subdomains and Its Specific Tests

Episodic Memory: *Capacity to correctly recall previous events, facts, and information with their situational context (Allen & Fortin, 2013; Tulving, 2002).*

AMIPB (Coughlan & Hollows, 1985): Participants completed a series of memory tests that comprised recall of a story, word list, and visual parallels of these measures. Each memory test included a delayed recall component (e.g., reproducing the figure recall test diagram following a 30-minute delay as accurately and quickly as possible).

Babcock Story Recall (Babcock & Levy, 1940; Horner et al., 2002): Participants listened to a brief story read by the assessor and received instructions to recall as many details immediately of the story as accurately as possible. Subsequently, the assessor repeated the story and evaluated the participant's 20-minute delayed recall.

BNT (Kaplan et al., 1983): Participants viewed line drawings of everyday objects (e.g., a tree) to less common things (e.g., an abacus) and named each of them. The number of objects could range from 30 to 60 items.

CVLT-LDFR (Delis et al., 2017): Participants received instructions to listen and recall words on a 16-item list following each of the five learning trials. Following a distractor list, participants were again instructed to retrieve words verbally spontaneously (short delay-free recall) (SDFR) and with categorical cues. After the longer delay, participants underwent a yes/no recognition trial that required them to differentiate between the target words in the prior 16-item list and 32 distractor list. The CVLT-LDFR score could range from 0 to 16.

HVLT (Benedict et al., 1998): Participants recalled as many words as accurately as possible immediately after listening to the experimenter saying the list following recurrent trials and after a time delay.

Memory Span Test (Bull & Scerif, 2001): Participants viewed stimuli (i.e., one to nine green spots or one to nine yellow spots) printed on white cards. Whereas the yellow spots were distractors, green spots were targets. The assessment began with the span size of one card, and three trials were conducted within each span size level. The test was discontinued if participants failed two trials within any span size that progressively grew longer. Otherwise, the test persisted insofar as the participants demonstrated accuracy on at least two out of three trials per span size.

RAVLT (Dierckx et al., 2011; Rosen et al., 1984): Participants completed a word list learning test of 10 unrelated words. The test began with five successive free recall trials and a delayed recall trial following a 20-minute duration of interference. Assessors verbalized 10 nouns with a 2s interval between each word for five immediate recall trials that prompted participants to repeat as many words they could remember after each trial as accurately as possible. The test also included a delayed recognition trial that asked participants to point out (yes or no) if each word from a list comprising 10 target words and 10 distractor words were part of the original list. Hits and accurate rejections were documented.

ROCFT (Rey, 1941, 1964): Participants viewed a complex figure and were tasked with the following four test components: (1) Copy trial (i.e., viewing the complex figure stimulus card and reconstructing the figure onto a blank paper); (2) Immediate recall (i.e., freely recalling and drawing the complex figure as accurately as possible 3 min after it has been removed and while engaging in other irrelevant verbal activity); (3) Delayed recall (i.e., freely recalling and reconstructing the complex figure half an hour after the Copy trial); (4) Recognition (i.e., identifying if various stimulus presentation immediately after the Delayed recall trial included stimulus figure elements).

Selective Reminding Test (Manghani et al., 2020): Participants had to recall a word list across six repeated immediate trials and after a 15-minute delay.

Spatial Recall Test (Manghani et al., 2020): Participants received instructions to reconstruct by hand a pattern of checkers shown to them for a short time. They completed three successive immediate trials of this test and were instructed to complete the fourth trial after a 15-min delay.

Attentional Control: *Basic ability to regulate mental focus on tasks consistent with a desired aim (Sorensen et al., 2018).*

Attentional Control – Executive Attention: *Ability to skillfully manage responses in the face of conflicting thoughts, emotions, and responses or conflict monitoring (Petersen & Posner, 2012).*

ANT – Executive attention (Fan et al., 2002; Posner et al., 2015): Participants had to classify as rapidly and accurately as possible if the central (target) arrow pointed left or right on double cue trials where flanker arrows pointed in the same direction (congruent trials) or opposite direction (incongruent trials). Executive control was computed by subtracting the average RT of congruent trials from the average RT of incongruent trials such that large positive scores signified poorer executive attention.

HTKS (Cameron Ponitz et al., 2008): Participants had to implement the correct action based on the assessor's instructions (e.g., "touch your toes," "touch your shoulders"). Higher counts of correct actions indicated better executive attention.

Peg tapping (Diamond & Taylor, 1996): Participants received a peg and had to tap the peg twice if the assessor tapped the peg once and vice versa. Higher counts of correct responses denoted better executive attention.

MEFS (Carlson & Zelazo, 2014): On this computerized task, participants had to sort virtual cards into one of the two boxes based on increasingly complex group of rules. Higher accuracy and lower RT indicated better executive attention.

Attentional Control – Orienting: *Honing focus on an object amid diverse sensory input or selective attention (Ristic et al., 2007; Sood & Jones, 2013).*

ANT – Orienting (Fan et al., 2002; Posner et al., 2015): Refer to the description above. Orienting was computed by subtracting the average RT on spatial cue trials from the average RT on center cue trials (both trials informed participants on target onset, but they received cues of spatial orienting only on spatial-cue trials).

ODT (Anderson et al., 2007; Hollingworth, 1998): Participants were asked to indicate whether objects were present in various unfolding visual scenes in a consistent way (e.g., chicken in a barn) or an inconsistent way (e.g., chicken in a classroom). It measured how participants targeted present-moment attention to the salient stimulus in ways uninformed by expectations.

STAN (Coull & Nobre, 1998): During each trial, participants attended to a central cue and two ancillary boxes that each consisted of a target (X or +). Participants received instructions to attend to the fixation cross, covertly identify the targets, and respond quickly and accurately by pressing a button with their preferred index finger. The display of targets preceded spatial cues predicting the target location (right or left); temporal cues forecasting the cue-target interval (i.e., "short" or "long" trials); or uninformative, neutral cues. Temporal and spatial cues were either valid (i.e., during 80% of trials, relaying the accurate location or cue-target interval) or invalid (relaying the opposite location or cue-target intervals). Participants received information that cues were "probably" valid. A practice block of each condition (temporal, spatial, or neutral) came before the experimental test that comprised nine blocks (each with 40 trials): in the order of three temporal, three spatial, and three neutral conditions. RTs after individually cued short temporal trials denoted how rapidly a participant could orient attention to the present moment and respond to unexpected events. RTs following neutral cues indicated the capacity to remain vigilant without any external temporal information and similarly orient attention to the present moment when the target unexpectedly disappeared.

Executive Functioning (EF): *Higher complex cognitive control functions responsible for governing cognitive and behavioral processes.*

Inhibitory Control: *Ability to refrain from autopilot response tendencies effortfully (Jewsbury et al., 2016).*

Backward inhibition (Koch et al., 2010; Mayr & Keele, 2000): This test is also known as the n-2 repetition cost and necessitates paradigms that comprise switching among ≥ 3 tasks. When shifting from Task A to Task B, it is thought that the inhibition of Task A is necessary. In this scenario, information linked to Task A was pertinent in the past, but it is no longer germane because Task B is now the task at hand. Shifting back to Task A after recently inhibiting it (A $\rightarrow$ B $\rightarrow$ A task sequence) ought to be more challenging than shifting to Task A in the absence of its latest inhibition (e.g., after C $\rightarrow$ B $\rightarrow$ A task sequence) due to the residual active inhibition of Task A. The comparative difference between sequences CBA and ABA in accuracy and/or RT indicated the extent of successful inhibition of Task A in the prior trial.

BART (Lejuez et al., 2002): On this computerized task, participants were assessed on their degree of risk-taking decision defined by the preference to pump the balloon in hopes of earning more money but at the risk of popping the balloon. The mean count of pumps for the balloon that went did not pop was an indicator of risk-taking.

Competitor rule suppression (Hsieh et al., 2012; Meiran et al., 2010): This test is based on the definition of a competing rule, i.e., a rule that produces a response that competes with the accurate response. For instance, if an experimental trial has a rule of Gender (i.e., necessitating a female-male choice and selecting the correct key), any task rule (e.g., Eye Color) that would require pressing the opposite key was the "competing rule." Based on this concept, "suppression" (i.e., inhibition) was evident if the prior competing rule shifted to become the pertinent one in the subsequent trial. Therefore, differences in accuracy and RT on trials wherein the present task rule was a competing task rule in the prior trial with all other kinds of trials wherein the current task rule was not the competing one at the previous trial indicated inhibitory control performance.

Delay of gratification (Esposito, 2015; Prencipe & Zelazo, 2005): Participants received instructions that as they progress through the test trials, they will gain a small amount of points if they clicked the little star or they can wait for the big star to gain a large

amount of points. Higher scores indicate a better ability to delay gratification to receive a bigger reward, denoted by a higher score eventually. Various similar versions of this task used in MBIs RCTs exist (e.g., SDT) (Solanto et al., 2001).

DTT (Esposito, 2015): Children received instructions from the assessor to sit with both hands on their laps and then saw the assessor present them with a box of attractive small toys. They received instructions to use words or verbalizations, rather than hands, to gesture which toys they intend to keep. Assessors rated participants' responses thrice on a 5-point Likert scale ranging from 0 (*hands stay on the lap, and the child only verbalizes*) to 5 (*child displays disinhibition by grabbing the toy/extensively digging into the box*).

Flanker test (Eriksen & Eriksen, 1974): Participants had to focus on the central target letter displayed on the computer screen and to press a button that matches the central target letter (either N or H) during congruent trials (e.g., NNNNN) and incongruent trials (e.g., NNHNN). Faster RT on incongruent trials denoted better inhibitory control.

Go/no-go (Hester et al., 2012; Stieben et al., 2007): Participants had to respond to each stimulus on each trial with a specific response based on the instructions during "go" trials (e.g., clicking the button when if the stimulus displayed in the trial was different from the previous trial) and withheld providing that specific response during "no-go" trials.

NEPSY-II (Korkmann et al., 2007): The NEPSY-II Inhibition A timed subtest was developed to evaluate the capacity to inhibit autopilot responses for novel responses and the capacity to shift between various response types among children and adolescents. RT was recorded.

RIT (MacLean et al., 2009; MacLean et al., 2010): Participants viewed single gray lines displayed one at a time in the middle of a black background on a computer screen and had to follow the instructions of responding as quickly and accurately with the left button (right index finger) to long lines (displayed 70% of the time) while inhibiting responses to infrequent short lines (shown 30% of the time). They were given auditory feedback signaling correct inhibitions in response to short lines ("ding"), incorrect answers to short lines ("whoosh"), and incorrect misses in response to long lines ("whoosh").

Simon task (Miyake et al., 2000): Participants responded to the arrow's direction displayed on the right, left, or middle of a black computer screen. Trials were congruent (e.g., a right-facing arrow on left side) or neutral (e.g., arrow placed in the middle). The primary outcome of interest was the proportion score: $(\text{mean incongruent RT} - \text{mean congruent RT}) / (\text{mean congruent RT})$.

Strategy application test (Levine et al., 2007): This assessment measures multitasking capacity regarding self-regulation and interference control. The assessment comprised six piles of 10 sheets with two items (big and small) and three kinds of time demand (short, medium, and long). Participants received instructions to trace two piles with drawings, two piles with written phrases that required coping on the bottom line, and two remaining piles with sets of figures wherein they were asked to write the numbers in each figure in ascending order. They received 100 points for each completed small item and 0 points for big items (i.e., the interference stimuli). The primary target was to attain the highest amount of points. The sheets at the start solely comprised short items, but subsequent sheets consisted of short, medium, and long items. The most optimal strategy consisted of engaging in the short ones and ignoring the rest (i.e., self-regulating). The task ended after completion of 50 items (not including the first page). Higher total number of brief items versus total number of items completed denoted better inhibition.

Stroop test (Stroop, 1935): Participants viewed matrices of color-words printed in blue, red, and green ink that were either congruent (e.g., "red" word with red ink) or incongruent (e.g., "red" word with blue ink) and were asked to name the ink color as rapidly and accurately as possible. RT and task accuracy were documented for this test.

Set-Shifting: *Capacity to switch back and forth between distinct thinking modes fluently (Berg, 1948; Chiu et al., 2018).*

DART – Set-shifting version: Participants attended to white and gray integers from 1 to 9 displayed sequentially in 28 cycles, which comprised three practice cycles. They were tasked to track the digit color, pressing "1" following white integers and "2" following gray digits, but always to refrain from responding after viewing the integer "3."

DCCS (Zelazo et al., 2013): Participants received instructions to arrange bivalent test cards first by one rule (e.g., color) and subsequently arrange the same cards by a second rule (e.g., shape). This test comprised three test blocks – pre-switch, post-switch, and mixed. First, participants completed the practice trials (i.e., four trials per each rule), and second, the pre-switch block (five trials). The post-switch block necessitated participants to arrange the cards by the second rule. The mixed block (40 trials) comprises alternation between the two rules.

HFT (Diamond et al., 2007; Wright & Diamond, 2014): Participants had to learn and adhere to a rule and subsequently shift to a second unique rule. For all conditions of this test, a red heart or flower appeared on the left- or right-hand side of the computer screen. In the congruent condition, one rule prevailed ("select the key on the identical side as the heart"). The incongruent condition asked students to recall a different rule ("select the key on opposite side of the flower"). Nonetheless, the incongruent trials necessitated students to inhibit the autopilot urge to respond on the side that displayed the stimulus. For the mixed condition, congruent and incongruent trials were intermixed.

SAT (Gualtieri & Johnson, 2006): Participants were required to switch from one instruction to another as accurately and quickly as possible by learning different rules and categories and making rapid decision-making.

Switch task (Rogers & Monsell, 1995): Participants saw a stimulus appear in 1 out of 4 2 by 2 grids and were instructed to provide a response on whether the stimulus was at the "upper" or "lower" part of the screen (on upper-lower trials) or "right" or "left" part of the screen (on right-left trials). Participants also underwent switch trials that randomly mixed upper-lower trials and right-left trials. Accuracy and RT were recorded.

Plus-minus task (Jersild, 1927; Miyake et al., 2000; Montgomery et al., 2005; Spector & Biederman, 1976): Participants received a sheet of paper with three lists of 30 two-integer digits (integers 10–99). For the first list, participants received instructions to add seven to each integer and pen down their responses. They received instructions to minus seven from each integer for the second list. For the third list, participants received instructions to shift between adding seven and subtracting seven. Participants had to complete each list as rapidly and accurately as possible. Assessors recorded their accuracy and RT on this task. Shifting cost was computed, i.e., percentage of time required to finish the switching list divided by the average time required to finish the plus and minus lists.

TMT-B (Army Individual Test Battery, 1944; Reitan, 1958): Participants were instructed to draw a continuous line when alternating between numbers (1-13) and letters (A-L) in ascending order. RT was recorded.

WCST (Grant & Berg, 1948): Participants were given four stimulus cards (mixture of shapes, colors, and numbers) across up to 64 or 128 trials for 10 to 20 minutes. Per the instructions, they sorted the cards based on specific rules (i.e., shape, color, or number) across trials and received feedback during each trial on whether their choice was correct or wrong.

Working Memory (WM): *Adeptness to continually monitor environmental input and replace out-of-date information with new information (Jha et al., 2019; Miyake et al., 2000; Vago et al., 2019).*

Anti-Saccade Task (Magnusdottir et al., 2019): Using an eye tracker, participants were instructed to direct their gaze as rapidly as possible at the cue (during pro-saccade trials) or away from the cue (during anti-saccade trials) across a series of trials. RT of accurate responses and accuracy rates during anti-saccade trials were recorded.

AOSPAN (Unsworth et al., 2005): Participants attended to a series of to-be-recalled stimuli that alternated with an irrelevant processing task (i.e., validating the accuracy of displayed math equations). Each block comprised 15 trials, with to-be-recalled items consisting of sets of 3 to 7 letters selected from a pool of 12 letters. Following the completion of each trial, participants chose the displayed items in the order they appeared in previously. OSPAN letters and equations stimuli were randomly displayed to prevent participants from viewing similar stimuli patterns across adjacent testing sessions. Higher total number of correct items indicated better WM.

BADS (Wilson et al., 2003): Participants were asked to plan and subsequently draw a route to visit six sites indicated on a zoo map while adhering to three rules. These rules constrained the most optimal choice, such that only four courses existed to solve this task accurately. The primary outcomes of this test were thinking time at the start (i.e., degree of anticipation, forethought, and planning) and the total score (i.e., the effectiveness of chosen route).

CDT (Owens et al., 2012, 2013): Participants were instructed to be attentive to the fixation cross, and then the side the arrow subsequently displayed on the screen was pointing. Following this, a mixture of red (target) and blue (distractor) rectangles was rapidly displayed in sequence on both sides of the central fixation cross. Participants needed to recall the red rectangles' orientation on the side the arrow pointed toward in the first array and to juxtapose it to the subsequent second array. Whereas no alteration in the rectangles' orientation occurred in 50% of trials, the rectangles' orientation altered in the other 50% of trials. Accuracy and RT of responses were recorded.

Delayed-Recognition Task (Jha et al., 2004; Jha & Kiyonaga, 2010): Participants received instructions to recall shoes or faces (stimuli that were challenging to describe easily) across a delay-spanning interval with distractors between the target stimuli for recall. The distractors had either neutral or negative valences to evoke diverse levels of emotional interference. Accuracy (i.e., percentage of correct responses) was the primary outcome of interest.

DSB (Wechsler, 2008): Participants listened to a series of number strings in ascending order of length and verbally iterated each digit string backward on each trial. Higher score indicated better WM performance. The WISC-IV (Wechsler, 1991) comprised a similar test for children and adolescents.

Figure Series (Hogrefe, 2008): Participants were instructed to choose to correct item in the series, which indicates their ability to deduce the pattern the series is based on and marked by their degree of accuracy.

Keep Track (Miyake et al., 2000): Participants recalled the last item from a list of words displayed sequentially on a computer screen that fell into preset categories (e.g., fruits, sports, relatives, etc.). They had to monitor and track classes that increased from one to four (comprising three trials per category). These categories were continually displayed at the bottom of the computer screen. Higher number of accurately recalled words indicated better WM.

LNS (Flanagan & Kaufman, 2009; Wechsler, 2008): Participants were instructed to remember and verbally reiterate alphanumeric strings read to them of increasing length in ascending order of the integers and letters in the string on each trial. Higher accuracy denoted better WM.

MET (Shallice & Burgess, 1991; Valls-Serrano et al., 2016): Participants completed a series of 11 tasks that assessed the capacity to develop and execute a plan in the natural environment in front of the assessor. These tasks could be grouped into three classes of goals: (1) completing a series of tasks (e.g., reserving a venue for a social gathering); (2) information-gathering on different environments (e.g., registering the address of a supermarket); and (3) meeting at a particular place before the beginning of a task. Different errors were classified during each task: (a) failures (i.e., not attaining a specific task goal); (b) rule violation (i.e., breaking a particular task or social rule); (c) inefficiencies (i.e., an alternative more efficient strategy could have been utilized).

MMQ (Troyer & Rich, 2002): Participants rated their perception of daily memory functioning on ability, contentment, and strategy use/knowledge domains. The study focused on the ability and contentment subscales since the strategy use/knowledge subscale captured compensatory behaviors due to memory problems instead of inherent memory functioning. Higher scores on the contentment subscale denoted stronger contentment with memory capacity, whereas higher scores on the ability subscale reflected more substantial daily memory mistakes.

Multiple object tracking paradigm (Meyerhoff et al., 2017; Pylyshyn & Storm, 1988): Participants viewed 16 randomly located similar white disks and a fixation cross at the center of the computer screen. To denote which disks the participants should track across a specific trial, contingent on the condition, two, three, four, or five disks changed color to red or green for two seconds. Subsequently, all disks changed to white again and stayed static before moving for a longer duration and next changing their direction by either a 22.5-degree angle or 44.5-degree angle. No "collisions" or overlaps occurred between disks, and they could "bounce off" if they touched the rectangular display area. Simultaneously, all disks flickered while moving. Participants received instructions to track all disks flagged at the start of the trial while retaining continual gaze on the fixation cross. Following the end of the trial, one of the 16 disks turned into its highlighted target color, and the participant responded to answer if it was one of the tracked disks or not. Higher accuracy indicated better WM capacity.

N-Back Task (Kane et al., 2007; Owen et al., 2005): Participants were instructed to retain information for a specific stimulus. Further, when a new stimulus substitutes the most prior one, the WM should update the information. Count of accurate responses and RT were indicators of WM performance. Similar variants of the n-back tasks used in previous MBIs RCTs exist (e.g., NIH-EXAMINER) (Kramer et al., 2014).

PASAT (Tombaugh, 2006): Participants listened to various number series through a prerecorded audiotape and were asked to continually verbalize the sum addition of the most recent two numbers.

Recent Probes Active Interference Task (Atkins et al., 2011; Nee et al., 2007): Participants completed 144 trials and received instructions to focus on a fixation cross for 1s and to memorize a target set of 6 letters that appeared on screen for the next 2s. Next, these letters were replaced by another fixation cross for 3s, followed by a single letter probe in the next 2s. Participants had to indicate by pressing a specific key whether or not the single-letter probe matched the recent target set or the opposite key otherwise. The trials were each spaced 1s apart. Each target set comprised three letters displayed in the prior target set and three new letters such that 50% of probes did versus did not match the preceding target. The task comprised four probe types, each occurring a-quarter of the time: "recent negative" (i.e., probes displayed in the previous but not the present target set); "non-recent negative" (i.e., was not displayed in the prior or current target sets); "recent positive" (i.e., probes displayed in the previous and present target sets); and "non-recent positive" (i.e., probes displayed in the present but not prior target sets). Subtracting error rates and RT on "non-recent negative" trials from those on "recent-negative trials" was a measure of proactive interference. The extent to which old material can enable acquisition of newer material was the accuracy performance on "non-recent positive" trials minus accuracy performance on "recent positive" trials.

Sternberg WM task (Sternberg, 1975): Participants received instructions to remember a string of letters and subsequently indicated as rapidly and accurately as possible if a probe was in the letter string across 54 trials. Higher accuracy denoted better WM ability.

TLT (Culbertson & Zillmer, 1998; Kovács, 2013): Participants were instructed to rearrange blocks across three pegs in ways that matched the picture shown to them with the least number of moves and shortest time possible. Variants of this test (e.g., Tower of Hanoi, etc.) typically included the following constraints: (1) shifting a block at a time; (2) for shifting a block underneath another block, shifting the top block first was necessary; (3) blocks could only remain on the peg than elsewhere on the test; and (4) minimizing the number of moves to solve the problem on each trial. The complexity of the task increased with every successful resolution of a trial.

5-point test (Regard et al., 1982): Participants had to draw as many figures as possible within sheets with five symmetrically organized dots by linking 2 to 5 dots with straight lines. They had to draw figures in an uninterrupted fashion and without any redundancies.

Verbal Fluency: *Capacity to generate as many relevant words based on a cue (e.g., semantic category, letter) within a time limit* (Henry & Crawford, 2004; Raucher-Chéné et al., 2017).

COWAT – Phonemic (Benton & Hampsher, 1978): Participants had to name as many unique words within 1 minute based on a phonemic cue (e.g., the letter "F," "A," or "S").

COWAT – Categorical (Delis et al., 2001): Participants had to name as many unique words within 1 minute based on a categorical cue (e.g., animal, vegetables, etc.).

S-letter (Aschenbrenner et al., 2001): Participants had to write as many words they could starting with the letter "S" in one minute under the following constraints: no inclusion of proper names, repetitions, and words that began with the same word stem; all words had to be German words written in German newspapers and books.

Word list generation (Manghani et al., 2020): Participants had to name as many unique animals as possible within 90 seconds.

Subjective Cognitive Functioning: *Perception of the degree one believes in their capacity to stay focused on task, process information, memorize facts, and exercise other cognitive functioning faculties (Daglas-Georgiou et al., 2022; Hallion et al., 2019).*

ACS (Derryberry & Reed, 2002; Judah et al., 2014): Participants rated their perception of how well they could generally focus on the task at hand and flexibly shift attention between different tasks.

ACTeRS (Ullmann et al., 1997): Teachers rated the degree of each participant's strength of attentional control via observation of classroom behaviors.

AFI (Cimprich et al., 2011): A 13-item self-report that captured subjective cognitive efficiency in everyday activities necessitating WM and attention (e.g., decision-making, executing tasks, focusing on conversations, planning, tracking thoughts in real-time, etc.).

ARCES (Cheyne et al., 2006): Participants rated the frequency they encountered daily mistakes due to inattention. Higher mean scores denoted more attention lapses/errors.

Attentional probes (Bastian & Sackur, 2013): Participants received probes while engaging in the task at hand to rate where their attention focus was just before the probe (e.g., 1 = *on-task* to 6 = *off-task*).

BRIEF-A (Roth et al., 2005): Participants rated their perception of executive functions (EFs) that comprise nine subdomains: emotional control, inhibition, initiate, planning/organization, self-monitoring, self-control, task monitoring, and WM. The developers of this measure have also designed similar BRIEF measures that capture parent and teacher reports of children and adolescents' behaviors linked to EF (Gioia et al., 2000).

CBCL – Attention scale (Achenbach, 1991): A subscale of the CBCL that evaluates the extent of attention control issues.

CDR (Morris, 1993): Clinicians rated global cognitive functioning of a patient with suspected neurocognitive impairment based on their observations on six subdomains (i.e., community affairs, housekeeping and hobbies, judgment and problem-solving, memory, orientation and personal care).

CFQ (Broadbent et al., 1982): Participants rated the frequency they encountered overall functional impairments in memory, motor functioning, and perception. A higher score denoted more substantial cognitive functioning errors.

DEX (Burgess et al., 1998): Participants and their immediate caregivers reported the participant's deficits in executive functioning, intentionality, and executive aspects of memory in everyday activities.

FSB (Cabrera et al., 2016; Grace & Malloy, 2001): Participants rated their symptoms of executive dysfunction (e.g., disorganization, multitasking issues) and disinhibition (e.g., high expressed emotions).

MAQ (Crook et al., 1992): Participants rated the degree to which their memory functioning was "somewhat poorer now" or "much poorer" compared to in the past.

MCQ (Dixon et al., 1988): Participants self-reported the extent to which they experienced memory problems, and responses of "agree" and "strongly agree" indicated subjective memory decline.

Self-reported cognitive function (Montazeri et al., 1999): Participants self-rated their perceived quality of global cognitive functioning.

SMQ (Sunderland et al., 1986): Participants completed a self-report of subjective memory assessment and a daily checklist of the frequency of memory failures.

SRS (Diehl et al., 2006): Participants rated their capacity to focus on the task at hand and to maintain emotional harmony and stability (e.g., "I can control my thoughts from distracting me from the task at hand.").

TRF – Attention subscale (Achenbach & McConaughy, 2003; Achenbach & Rescorla, 2001): Teachers rated the degree to which the students recruited in the current study displayed attention problems (i.e., inattention and hyperactivity).

YSR – Attention subscale (Achenbach & Rescorla, 2001): Participants self-reported the degree of attention problems they typically experienced with this 9-item measure.

Sustained Attention Accuracy: Degree of correctness and consistency with staying on-task (Esterman & Rothlein, 2019).

Sustained attention has also been defined as alerting (essential arousal or awareness of objects) (Prakash et al., 2020).

Attentional blink test (Dale & Arnell, 2013; van Leeuwen et al., 2009): Participants viewed arrays of 13-17-letter strings presented swiftly 1 second per letter, and two integers were included in the letter string (i.e., "T1" and "T2"). The display of T2 occurred at a duration of two, four, or eight items from T1. Though accurate detection of T1 tends to be high, T2 becomes more challenging to detect if it displays between 200ms-500ms. This phenomenon is called the "attentional blink," i.e., the lagged duration in which attentional resources tend to be constrained to efficiently and effectively cognitively process T2. Assessors computed the proportional accuracy score for the different lag times between T1 and T2 (van Vugt & Slagter, 2014).

CAT (Cambraia, 2003): Participants received instructions to mark only three kinds of triangles among distractors, all randomly spread in rows on a sheet of paper.

CPT (Corbett et al., 2009; MacLean et al., 2010): Participants received instructions to focus on the screen, saw one integer appear on the screen at a time, and had to press the spacebar when a specific number (e.g., the integer "6") or letter (e.g., "K" or "X") appeared. In the AX-CPT version (Braver, 2012; Servan-Schreiber et al., 1996), participants were told to offer a target response to an "X" probe after an "A" cue and to offer a non-target response for other kinds of non-target trials: cue "A" and subsequently a "non-X" probe letter (i.e., "AY" trial); a "non-A" and subsequently an "X" probe letter (i.e., BX trial); and a "non-A" cue and subsequently a "non-X" probe letter (i.e., "BY" trial). Higher number of accurate responses indicated better sustained attention ability.

d2 Test of Attention (Brickenkamp et al., 2010; Brickenkamp & Zillmer, 1998): Participants viewed a d2 sheet that consisted of 14 lines of letters. Their task was to strike out *ds* with two dashes with distractors in between as accurately and rapidly as possible within 20s.

DSF (Wechsler, 2008): Participants listened to a series of number strings in ascending order of length and verbally iterated each digit string forward on each trial. Higher score indicated better sustained attention. The WISC-IV (Wechsler, 1991) comprised a similar test for children and adolescents.

Gibberish detection task (ZanESCO et al., 2016): Participants had to read the text of a children's book while tracking moments where the sentences or phrases turned "gibberish" (e.g., "We must make circus for the money" instead of "We must make money for

the circus") and to respond in that instance by clicking the "G" button on the keyboard. Higher counts of identified gibberish episodes denoted better sustained attention.

Hotel Test (Burgess et al., 2006; Manly et al., 2002): Participants experienced a simulation of a workplace that requires multitasking by receiving materials for five clerical jobs (compiling bills, searching phone numbers, sorting finances, sorting name tags, and proofreading a pamphlet) and a prospective memory job (following instructions to click a button to "open" and subsequently "close" a "garage door" during preset times). They had to complete these tasks while imagining "running a hotel" across 15 minutes, with a clock nearby to manage their time and responses. Hotel test scores included three subdomains: total number of clerical tasks tried (out of five instructed); (2) variation from the best amount of time to spend on each task (3 minutes) considering the global goal of trying each task in the given total test time; and (3) variation from the "garage door" times based on the instructions, denoted as a score from 0 (unsuccessfully clicking the button) to 8 (clicking the button within 60 seconds of both instructions).

SART (Robertson et al., 1997; Stanislaw & Todorov, 1999): Participants viewed a continuous array of integers (1–9) or letters (A–Z), one per trial, and received instructions to refrain from pressing the space bar in reaction to viewing a specific integer (e.g., the integer "3") or letter (e.g., the letter "X") that was the target, but to press the space bar in reaction to all other letters or numbers (i.e., non-targets) with their dominant hand. Higher accuracy denoted better sustained attention ability. A' , a parametric marker of sensitivity, was computed with "false alarms" (errors in response to non-targets) and "hits" (accuracy in response to targets) to take into account and adjust for unequal weighing of different trials.

TEA (Robertson et al., 1996): Participants completed a series of eight subtests (standardized in a manner parallel to WAIS-III and WMS-III) that captured sustained attention and selective attention. For instance, the Map Search subtest required participants to find symbols (e.g., fork and knife, which signified restaurants) on a city map. The Elevator Counting required participants to count tones to determine which floor an elevator was on after the assessor asked them to imagine being in an elevator with malfunctioned floor indicators. The child version of this test comprised five subtests (Manly et al., 1999).

TVAT (Vangkilde et al., 2011): This accuracy-based measure instructed participants to attend to a series of letter(s) across various trials and to key in the letter(s) they viewed subsequently. During whole report trial, the task either displayed two or six target letters, whereas partial report trials comprised two red targets and four blue distractor letters. Whereas presentations with six target letters varied in stimulus durations (10 to 200ms), all other presentations occurred for 80ms. Participants responded with all red letters they were "fairly confident" of viewing without pure guessing and without time constraints, and higher accuracy denoted better sustained attention.

Intra-Individual Coefficient of Variation: *Degree of variability in offering accurate responses on sustained attention tasks (Bellgrove et al., 2004; Cubillo et al., 2023).*

DART (Dockree et al., 2006; Robertson et al., 1997): Participants underwent procedures similar to the SART with the addition of a CPT to enhance the sensitivity of capturing sustained attention in healthy adults. Higher RT coefficient of variation (CV) for white integers denoted poorer overall DART performance.

SART (Bastian & Sackur, 2013; Robertson et al., 1997; Stanislaw & Todorov, 1999): Standard deviation of the participant's RTs by their mean RT for non-target trials. Higher ICV indicated lower consistent processing speed and more subjective mind wandering.

Processing Speed: Degree of task completion efficiency (Muller et al., 2021).

LDST (Lezak et al., 2012; Smith, 1982; van der Elst et al., 2006): This assessment was adapted from earlier substitution tests, i.e., the Symbol Digit Modalities Test (SDMT) and the Digit Symbol Substitution Test (DSST). The DSST required participants to attend to a symbol-letter key and to write down the matching symbol beneath each digit in a blank space. In contrast, the instructions for SDMT were reversed (i.e., participants received instructions to write down the matching number). Simultaneously, participants could also verbalize answers for the DSST. The LDST differed from the earlier versions by including "over-learned" symbols, i.e., letters and numbers. Therefore, participants received instructions to learn the digit-letter connections, whereas other substitution tests required participants to acquire abstract symbols.

SART (Robertson et al., 1997; Stanislaw & Todorov, 1999): Mean RT on the SART described in the sustained attention subdomain above.

TMT-A (Army Individual Test Battery, 1944; Reitan & Wolfson, 1993; Reitan, 1958): Participants received instructions to draw straight lines to connect 25 circles numbered consecutively from 1 to 25 as rapidly and accurately as possible. Faster RT denoted better processing speed.

Symbol Search (Wechsler, 2008): Participants received instructions to mark a checkbox (with either "yes" or "no" responses) with a pencil and provide as many responses to items as accurately as possible within 2 minutes. Each item was printed sequentially on a row. Each row displayed two symbols to the left and five to the left. The correct answer was "yes" if one of the sets of five symbols corresponded with one of the two symbols on the left. Matching symbols occurred half the time, and higher total accurate responses for positive and negative responses denoted better processing speed.

Vigilance Face Recognition (Solso & McCarthy, 1981; Wimmer et al., 2016): Participants viewed 10 pictures of adult male faces that appeared one at a time on a computer screen and had to recall each picture correctly. Following an acquisition phase, a 5-minute break occurred during which participants engaged in the Stroop test. Subsequently, the recognition stage of this vigilance face recognition test occurred. Ten faces were displayed again, one at a time, such that five consisted of the ones seen before, and two were novel. The remaining three images were morphs of three of the previously shown faces. Participants had to indicate quickly and accurately if each face shown was previously displayed. Higher accuracy and quicker rejections of morphed faces suggested better processing speed.

Visual Search Test (Biederman et al., 1973; Biederman et al., 1982): Participants first viewed an object (i.e., prime) and followed a picture of a daily scene borrowed from a children's book (e.g., a platform at a train station). They had to respond as rapidly and accurately as possible if the image included the prime object. The specific picture included the prime in its original form and an expected location (e.g., cloud in a sky), the prime in an unexpected place (e.g., cloud in front of a wall), or did not include the prime. Better accuracy in identifying prime objects even in expected locations and in accurately rejecting black trials reflected better processing speed.

Cognitive Errors: *Mistakes by commission or omission (Fetterman & Robinson, 2011).*

CPT (Corbett et al., 2009): Number of omission errors (i.e., non-response to target stimulus) and number of commission errors (i.e., response to non-target stimulus) were documented.

d2 Test of Attention (Brickenkamp, 2002): Higher total error rate (i.e., commission errors and omission errors divided by total possible accurate responses), the error percentage (total errors divided by total processed responses multiplied by 100), and the error distribution (i.e., error sums for the three assessment sections – lines 1-5, lines 5-10, and lines 11-14) indicated more cognitive errors.

DART (Dockree et al., 2006; Robertson et al., 1997): Premature presses, commission errors, and response omissions were recorded.

SART (Cheyne et al., 2011; Robertson et al., 1997): Higher commission errors (i.e., pressing the space bar when they were not supposed to in response to the target) denoted more problems with inhibitory control. Higher omission errors (i.e., not pressing the space bar when they were supposed to) marked more problems with sustained attention.

Stroop test (Stroop, 1935): Stroop errors referred to those that occurred solely within the incongruent condition.

Global Cognition: *Composite of all said cognitive subdomains herein.*

ADAS-Cog (Kueper et al., 2018; Mohs et al., 1997): Participants completed 11 tests that assessed different self-reported and observer-rated aspects of cognitive functioning. These tests comprised cognitive functioning subdomains of language, memory, and praxis. Specific assessments include commands (i.e., executing tasks based on specific instructions), constructional praxis (i.e., copying shapes shown), ideational praxis, language, orientation, naming objects and fingers, word recall, and word recognition.

MOCA (Nasreddine et al., 2005): A brief clinician-administered neurocognitive assessment that includes abstract reasoning, attention, language, orientation to time and place, short-term memory, and visuospatial function.

MMSE (Folstein et al., 1975): A brief clinician-administered neurocognitive test that captures subdomains including attention, language, orientation, short-term memory, and visual construction.

RBANS (Randolph, 1998): A neurocognitive test that is slightly longer than the MoCA and MMSE and comprises five cognitive functioning subdomains (i.e., attention, delayed memory, immediate memory, language, visuospatial function/constructional praxis) spread across 12 subtests.

Note. A'=objective task performance; ACS=attention control scale; ACTeRS=ADHD Comprehensive Teacher Rating Scale; ADAS-Cog = Alzheimer's Disease Assessment Scale-cognitive subscale; ADHD=attention deficit hyperactivity disorder; AFI=attentional function index; AMIPB=adult memory and information processing battery; AOSPAN=automated operation span task; ANT=attention network test; ARCES=Attention-Related Cognitive Errors Scale; BADS=behavioral assessment of the dysexecutive syndrome; BART=balloon analogue risk task; BNT=Boston naming test; BRIEF-A=behavior rating inventory of executive function-adult version; BRIEF-SR=behavior rating inventory of executive function-self-report version; CAT=concentrated attention test; CBCL=child behavior checklist; CDR=clinical dementia rating; CDT=change detection task; CFQ=cognitive failures questionnaire; COWAT=controlled oral word association task; CPT=continuous performance test; CVLT-LDFR=California verbal learning test-long

delay-free recall; DART=dual attention response task; DCCS=dimensional change card sort task; DEX=dysexecutive questionnaire; DSB=digit span backward; DSF=digit span forward; DTT=Dinky toys task; FSB=frontal systems behavior scale; HFT=hearts and flowers task; HTKS=head toes knees shoulder test; HVLT=Hopkins test of verbal memory-revised; LDST=letter-digit substitution task; LNS=letter-number sequencing; MAQ=metamemory in adulthood questionnaire; MBI=mindfulness-based intervention; MEFS=Minnesota executive function scale; MET=multiple errands test – contextualized version; MOCA=Montreal cognitive assessment; MCQ=memory complaints questionnaire; MMQ=multifactorial memory questionnaire; MMSE=mini-mental state examination; NEPSY-II=Developmental Neuropsychological Assessment; ODT=object detection task; OSPAN=operation span task; PASAT=paced auditory serial addition task; RAVLT=Rey Auditory Verbal Learning Test; RBANS=repeatable battery for the assessment of neuropsychological status; RCT=randomized controlled trial; RIT=response inhibition task; ROCFT=Rey-Osterrieth complex figure test; RT=response time; TLT=Tower of London test; SART= sustained attention response task; SAT=shifting attention test; SDMT=symbol digit modalities test; SDT=star delay task; SMQ=Sunderland memory questionnaire; SRS=self-regulation scale; STAN=spatial and temporal attention network; TEA=test of everyday attention; TEA-Ch=test of everyday attention for children; TMT=trail making test; TRF=teacher-report form; TVAT=test of visual attention; YSR–attention=youth self-report–attention syndrome subscale; WCST=Wisconsin card sorting test; WISC-IV=Wechsler Intelligence Scale for Children-Fourth Edition.

Table 2

Effects of MBIs on Global Cognition and Unique Cognitive Subdomain Outcomes in Comparison to No-Treatment or Waitlist

Cognitive outcome	ES_N	k	N	Hedge's g	95% CI	Q	I^2	p -uniform
Global Cognition	322	60	3691	0.583^{***}	[0.312, 0.854]	$Q(df=321)=678.25^{***}$	73.65	-1.65
Orienting	15	10	957	0.323	[-0.310, 0.956]	$Q(df=14)=20.59$	34.78	-1.43
Executive Attention	22	16	1286	0.301^{***}	[0.136, 0.466]	$Q(df=21)=28.66$	38.50	-0.22
WM Accuracy	34	19	2639	0.326^{***}	[0.178, 0.475]	$Q(df=33)=65.20^{***}$	47.54	-2.12
WM Latency	18	7	1566	0.382	[-1.690, 2.450]	$Q(df=17)=28.89^*$	67.16	-1.73
Inhibition Accuracy	31	19	1559	0.643[*]	[0.054, 1.230]	$Q(df=29)=90.53^{***}$	72.09	-2.69
Inhibition Latency	20	11	1060	0.111	[-0.071, 0.293]	$Q(df=19)=21.33$	7.58	-2.34
Shifting Accuracy	16	8	745	0.272^{**}	[0.076, 0.468]	$Q(df=15)=16.56$	12.15	-1.12
Shifting Latency	11	9	659	0.00037	[-0.586, 0.587]	$Q(df=10)=16.66$	53.57	0.00
Sustained Attention Accuracy	42	17	2108	0.376^{***}	[0.170, 0.581]	$Q(df=41)=251.28$	84.96	-1.71
Intra-Individual Coefficient of Variation	7	5	401	0.036	[-2.364, 2.440]	$Q(df=6)=8.886$	36.84	-0.18
Subjective Cognitive Functioning	32	16	2421	0.257^{***}	[0.171, 0.344]	$Q(df=31)=26.16$	16.83	-0.35
Processing Speed	7	6	415	0.976	[-1.650, 3.600]	$Q(df=6)=27.13^{***}$	76.85	-0.67
Verbal Fluency	3	3	189	0.070	[-0.218, 0.358]	$Q(df=2)=1.35$	8.79	0.00
Episodic Memory	10	6	494	0.081	[-0.087, 0.249]	$Q(df=9)=6.51$	0.00	0.00
Cognitive Error	27	13	1153	0.180	[-0.198, 0.556]	$Q(df=26)=41.70^*$	36.51	-2.14

Note. ^{*} $p \leq .05$; ^{**} $p \leq .01$; ^{***} $p \leq .001$.

MBI=mindfulness-based intervention; k =number of studies; ES_N =number of effect size comparisons between mindfulness-based intervention and a comparison group; N =sample size pooled across various studies; CI=confidence interval around average parameter estimate; Q =a standardized indicator for the degree of homogeneity of effect sizes concerning the average effect size; I^2 =a metric for the proportion of observed variability that indicates real effect size variability; WM=working memory.

Table 3

Effects of MBIs on Global Cognition and Unique Cognitive Subdomain in Comparison to Active Controls

Cognitive outcome	ES_N	k	N	Hedge's g	95% CI	Q	I^2	p - uniform
Global Cognition	374	72	5847	0.208***	[0.118, 0.298]	$Q(df=373)=528.83^{***}$	40.62	-2.60
Orienting	10	6	733	0.303	[-0.338, 0.944]	$Q(df=9)=16.60$	63.55	-1.70
Executive Attention	19	14	1686	0.192***	[0.078, 0.306]	$Q(df=18)=18.39$	0.00	0.11
WM Accuracy	37	25	2658	0.296**	[0.101, 0.490]	$Q(df=37)=113.27$	66.04	-0.69
WM Latency	12	8	749	0.105	[-0.108, 0.317]	$Q(df=11)=6.00$	0.00	0.00
Inhibition Accuracy	22	12	1221	0.192**	[0.076, 0.307]	$Q(df=21)=16.99$	0.00	-0.95
Inhibition Latency	20	12	1182	0.015	[-0.702, 0.731]	$Q(df=19)=32.78^*$	65.20	-2.28
Shifting Accuracy	18	10	1007	0.200**	[0.058, 0.341]	$Q(df=17)=26.50$	47.94	-0.30
Shifting Latency	18	13	1034	-0.028	[-0.176, 0.120]	$Q(df=17)=26.10$	7.15	-1.76
Sustained Attention Accuracy	54	23	3083	0.212***	[0.100, 0.325]	$Q(df=53)=108.62^{***}$	61.67	-0.29
Intra-Individual Coefficient of Variation	12	9	660	0.337**	[0.184, 0.490]	$Q(df=11)=17.67$	38.32	-1.34
Subjective Cognitive Functioning	72	28	4278	0.394***	[0.190, 0.597]	$Q(df=71)=414.30^{***}$	80.43	-0.81
Processing Speed	13	6	560	0.381	[-0.741, 1.504]	$Q(df=12)=17.91$	50.20	-0.82
Verbal Fluency	11	7	852	0.119	[-2.300, 2.535]	$Q(df=10)=9.17$	28.07	0.00
Episodic Memory	22	10	1401	0.073	[-0.273, 0.420]	$Q(df=21)=13.65$	0.00	0.00
Cognitive Error	30	8	1228	0.094	[-2.219, 2.410]	$Q(df=29)=19.12$	2.10	0.85

Note. * $p \leq .05$; ** $p \leq .01$; *** $p \leq .001$.

MBI=mindfulness-based intervention; k =number of studies; ES_N =number of effect size comparisons between mindfulness-based intervention and a comparison group; N =sample size pooled across various studies; CI=confidence interval around average parameter

estimate; Q =a standardized indicator for the degree of homogeneity of effect sizes concerning the average effect size; I^2 =a metric for the proportion of observed variability that indicates real effect size variability; WM=working memory.

Figure 1

PRISMA Flowchart Summarizing the Study Identification, Screening, and Selection Process

Note. MBI=mindfulness-based intervention; PRISMA=preferred reporting items for systematic reviews and meta-analyses; RCT=randomized controlled trial.

Figure 2

Forest Plot of MBIs on Global Cognition and Unique Cognitive Subdomain Outcomes in Comparison to No-Treatment or Waitlist

Note. MBI=mindfulness-based intervention; WM=working memory.

Figure 3

Risk-of-Bias Plot for MBIs Versus No-Treatment or Waitlist

Figure 4

Forest Plot of MBIs on Global Cognition and Unique Cognitive Subdomain Outcomes in Comparison to Active Controls

Note. MBI=mindfulness-based intervention; WM=working memory.

Figure 5

Risk-of-Bias Plot for MBIs Versus Active Control