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CLINICAL REVIEW

Insomnia and cognitive performance: A systematic review and meta-analysis

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SUMMARY

Cognitive performance has been extensively investigated in relation to insomnia, yet review of the literature reveals discrepant findings. The current study aimed to synthesize this literature with a systematic review and meta-analysis. 48 studies (k = 50 independent samples, n = 4539 total participants) met inclusion criteria. Omnibus meta-analysis revealed insomnia was associated with poorer overall cognitive performance (Hedge's $g = -0.24$, $p < 0.001$). Analyses by cognitive domain revealed insomnia was specifically associated with impairments in subjective cognitive performance ($g = -0.35$), and objective measures of perceptual function ($g = -0.24$), manipulation ($g = -0.52$) and retention/capacity in working memory ($g = -0.30$), complex attention ($g = -0.36$), alertness ($g = -0.14$), episodic memory ($g = -0.29$), and problem solving in executive functions ($g = -0.39$). Age, percent female, publication year, and insomnia measure did not consistently moderate findings. Approximately 44% of studies failed to use diagnostic criteria when categorizing insomnia and cognitive measures varied widely. This indicates a need for standardization of methods assessing insomnia and cognitive performance in research. Overall, findings from this meta-analysis indicate insomnia is associated with impairment in objective and subjective cognitive performance, highlighting the utility of treating insomnia to potentially improve cognitive outcomes.

Introduction

Insomnia is the most prevalent sleep disorder, affecting approximately 10–30% of the population worldwide [1]. Insomnia has been operationally defined in various ways by previous literature, ranging from a single question about difficulty sleeping, to diagnosis by polysomnography through overnight sleep study [2]. Insomnia is both a physically and economically demanding disorder. It is associated with higher levels of functional impairment, higher frequency of depressive disorder, and a greater prevalence of chronic illness, contributing to an increased frequency of medical visits and missed work [3–7].

In addition to the negative economic and physical impacts of insomnia, the disorder has been associated with diminished cognitive performance [8]. Cognitive performance definitions vary widely by study, but are typically operationalized as either subjective (i.e., assessed via self-report) or objective (i.e., assessed via a cognitive task or test). The relationship between insomnia and poorer cognitive performance is of particular importance due to the widespread negative effects of cognitive disturbance, including lower quality of life [9], increased costs of care [10], and increased rates of motor vehicle accidents [11], work place accidents [12], and mortality [13]. A better understanding of the impact of insomnia on cognitive performance may inform potential intervention efforts to reduce the burden of poor cognitive performance on health, safety, and well-being. Further, given that insomnia is commonly comorbid with other physical and mental health conditions [1,14], it is possible that cognitive deficits associated with insomnia could be exacerbated or even moderated by the comorbid conditions associated with insomnia.

The current state of research uses the classification of "insomnia" in a variety of ways, creating a nebulous understanding of what

Abbreviations: BHHR, Borenstein, Hedges, Higgins, and Rothstein; CI, Confidence interval; CPT, Conners continuous performance test; DSM, Diagnostic and Statistical Manual of Mental Disorders; ICSD-3, International Classification of Sleep Disorders, Third Edition; MMSE, Mini-mental status exam; QE, Cochran's QE.

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symptoms actually constitute insomnia. Insomnia can refer to complaints about one's sleep (e.g., “I have trouble sleeping”), the presence of symptoms of insomnia disorder assessed via a self-report scale (e.g., Insomnia Severity Index), or a diagnosable insomnia disorder using clinical criteria (e.g., Diagnostic and Statistical Manual of Mental Disorders). In one review of epidemiological studies, insomnia prevalence rates ranged between 3.2 and 42% across various populations [15]. As described by Ohayon and Reynolds (2009), this wide range in prevalence rates is likely attributable to the various meanings that are applied to the word “insomnia” in research.

Although the negative consequences of insomnia on cognitive performance have been supported by existing research [16,17], results are mixed across types of insomnia definition (e.g., clinically diagnosed insomnia, insomnia complaints), cognitive domains (e.g., working memory, attention) [18], and type of cognitive impairment measure (i.e., subjective vs. objective). Although data exist to support the significant effect of insomnia on both subjective and objective cognitive performance, (e.g., [19,20]) some studies only find differences in subjective cognitive performance (e.g., [21–23]). These discrepant findings highlight the need for a comprehensive synthesis of the current literature.

Previous meta-analysis

In their 2012 meta-analysis on insomnia and cognitive performance, Fortier-Brochu and colleagues [8] outline multiple cognitive domains measured in studies that assess the relationship between insomnia and daytime cognitive performance [8]. Their meta-analysis provided a quantitative summary of the 24 studies investigating the differences between the cognitive performance of people with insomnia and people without insomnia on multiple cognitive domains [8]. Those with insomnia exhibited significantly impaired episodic memory ($d = -0.51$), problem solving ($d = -0.42$), manipulation in working memory ($d = -0.42$), and retention in working memory ($d = -0.22$). However, there were no differences between groups in general cognitive functioning, perceptual and psychomotor processes, procedural learning, verbal functions, different dimensions of attention, or aspects of executive functioning.

Due to the small number of effect sizes per domain, this previous meta-analysis was unable to examine any demographic or methodological moderators of the relationship between insomnia and cognitive performance to better understand potential sources of heterogeneity in their results. Previous research has demonstrated that there are significant age and gender differences in both insomnia and cognitive performance [18,24]. Age and gender may therefore be important moderators to assess when investigating the relationship between insomnia and cognitive performance.

Given the mixed nature of previous studies' methods and results, as well as the increasing attention toward research on insomnia and cognitive performance since the previous meta-analysis was published [8], an updated systematic review and meta-analysis of the existing literature is warranted. Increased knowledge on this topic could allow for the development of more comprehensive, sensitive, and empirically supported assessments of both objective and subjective cognitive performance, while also emphasizing the need for an operationalized definition of insomnia. Systematic examination of demographic and methodological moderators of the relationship between insomnia and cognitive performance will also elucidate sources of heterogeneity of results and better characterize who may be most at risk.

The current study

This systematic review and meta-analysis synthesized results of studies examining the association between insomnia and cognition and elucidated the sources of heterogeneity to inform future research. Specifically, the current study aimed to:

1) Execute a systematic review of existing research on insomnia and cognitive performance and identify differences in study design, sample characteristics, cognitive domains assessed, criterion used for insomnia, and results.
2) Analyze grouped effect sizes gathered from the literature reviewed and assess the overall relationship between insomnia and cognitive performance, as well as the relationship by cognitive domain.
3) Evaluate the impact of demographic and methodological moderators on the relationship between insomnia and cognitive performance (e.g., sample age and gender, type of insomnia measurement [clinical diagnosis vs. validated scale or single item], and publication date).
4) Investigate publication bias, or the “file drawer effect” in the existing body of research.
5) Consolidate findings to identify the need for, and guide the direction of, future research.

Methods

The systematic review was guided by the established guidelines of both the Meta-Analyses and Systematic Reviews of Observational Studies [25] and the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [26]. Two online databases (PubMed and PsychINFO) were searched to retrieve studies investigating the relationship between insomnia and cognitive performance. The search of these two databases revealed a total of 1515 studies to be reviewed. The resulting studies were reviewed for inclusion by two independent reviewers, and discrepancies were resolved through discussion.

Search strategy

Search terms for the systematic review included: insomnia AND 1) “cognitive function”, 2) “cognitive performance”, 3) cognition, and 4) neuropsychology. Duplicates were removed, and two independent raters screened the titles and abstracts of the search results for the exclusion criteria described below. The two raters then adjudicated all discrepancies. A flow-chart graphic is presented to outline the number of studies excluded at each step and reasons why (Fig. S1). Cohen's kappa coefficient (κ) was calculated as an indicator of inter-rater agreement for categorical items. For the present study $\kappa = 0.79$, indicating substantial or excellent agreement between the raters [27].

Inclusion criteria

During the screening phase, studies were first included if they met the following criteria: 1) insomnia assessed and 2) cognitive performance assessed.

Exclusion criteria

Following the initial inclusion screen, studies were excluded for the following reasons: 3) animal study, 4) not an empirical study (e.g., did not collect data through direct or indirect observation), 5) did not include a control group, 6) did not provide enough information to determine effect size, or 7) full text was not available. The investigators attempted to contact all corresponding authors of articles excluded for criteria 6) and 7) to request access to the data necessary to include the studies in analyses. This review includes all articles that meet the aforementioned criteria and were published prior to January 1st, 2019.

Data extraction

The systematic review resulted in 48 articles that were eligible for inclusion in the meta-analysis. Two of the articles included data for two independent insomnia groups and two independent control groups (i.e., short and long sleep duration groups [28], Parkinson's and non-Parkinson's groups [29]), which we treated as independent samples. This resulted in k = 50 unique samples that were included in the meta-analysis. The study team developed an evidence table (available upon request, select data outlined in Table S1) to be completed based on the guidelines outlined by the Strengthening the Reporting of Observational Studies in Epidemiology group [30]. Both independent raters extracted all data from the 48 included articles, assessed study quality using a standardized measure (Table S2), and categorized each measure by distinct cognitive domain used (Table S3). The categorization of cognitive domains was completed using definitions from the previous meta-analysis [8] to facilitate comparison and continuity in the research (Table S4). The primary author then resolved discrepancies in extracted information, and the file was uploaded into the statistical program R for data analysis [31].

Data analysis

Aggregating effect sizes

In order to analyze the data collected, the open-source R packages “meta,” [32] “MAd,” [33] “compute.es,” [34] and “metafor,” [35] were used. First, we computed the Hedge's g effect sizes from each study using the “meta” and “compute.es” package. The direction of effect size values was adjusted so that a negative value would always indicate a poorer performance in insomnia groups compared to controls. Given that the same studies often provided multiple measures of each dependent variable within the same cognitive domain (e.g., three measures assessing general cognitive function) we implemented the Borenstein, Hedges, Higgins, and Rothstein (BHHR; [36]) method in order to aggregate dependent effect sizes within cognitive domains within studies [34]. The BHHR procedure has been shown to be the least biased and most precise method by which to aggregate effect sizes [33]. Once this aggregation procedure was completed in R, each independent sample then contributed only one effect size for each cognitive domain it assessed. For the omnibus meta-analysis, we further aggregated effect sizes across cognitive domains within independent samples, so that each of the 50 samples only contributed one effect size.

Omnibus meta-analysis

An omnibus meta-analysis was conducted to examine the overall effect of insomnia on cognitive performance across all cognitive domains and studies. To avoid accidental invalid pooling of heterogeneous samples, we used combination pooling methods as opposed to simple pooling estimates [37]. Given the lenient exclusion criteria for this meta-analysis, a random effects model was used, which allows for the true effect size to vary between studies [38]. Moderation analyses were then conducted to determine if average total sample age, percent female, study year, study quality, or insomnia measure (clinical or diagnostic criteria vs. any other type of measure) moderated effect sizes.

Objective cognitive performance

Given the distinct nature of subjective and objective measures of cognitive performance, meta-analyses were then conducted separately for these measures. For the objective measures, to replicate findings from Fortier-Brochu et al. (2012) [8], main effect and moderated meta-analyses were conducted separately by each of the 17 types of objective cognitive domains (Fig. 1).

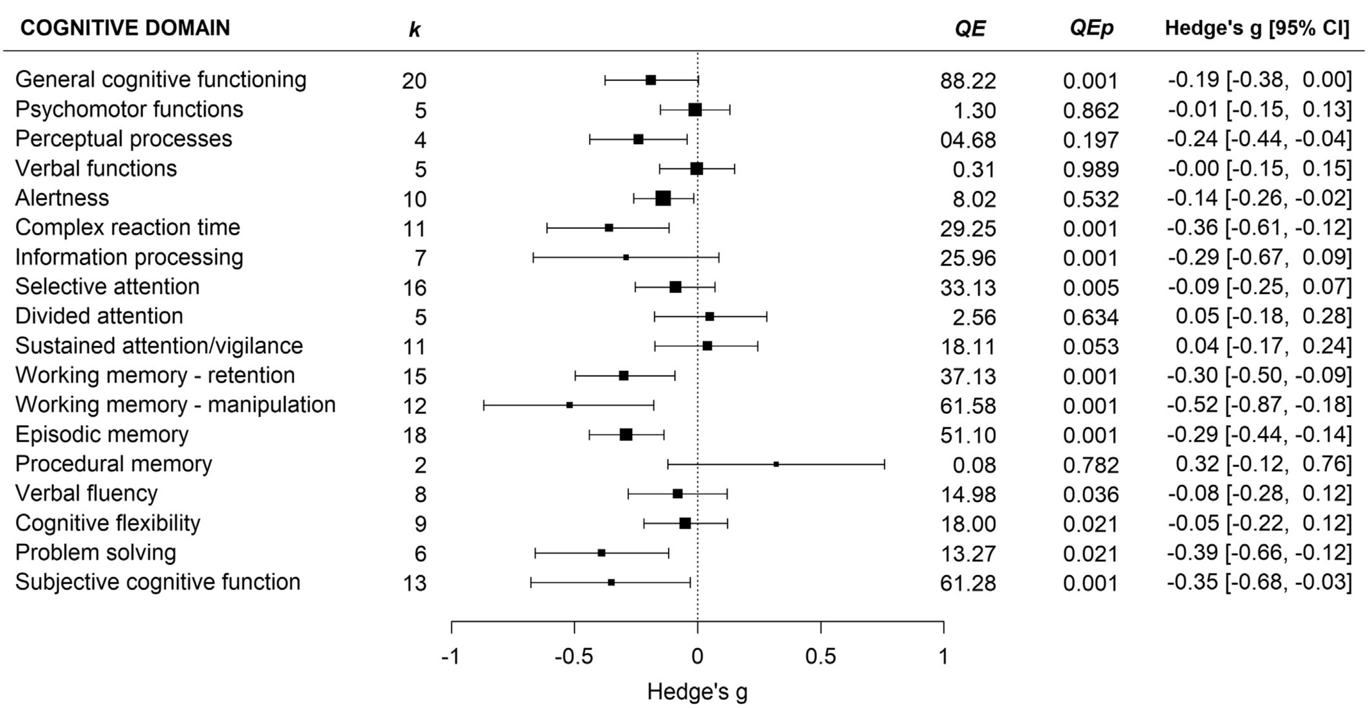

Fig. 1. Forest plot for meta-analyses separated by cognitive domain. Results are depicted as Hedge's g [95% Confidence Interval]. The size of the squares depict the relative weight (inversed variance of the discrepancy measure) of each domain. k = number of studies available for cognitive domain aggregate effect size. QE = statistic of residual heterogeneity. QEp = p-value of residual heterogeneity.

Subjective cognitive performance

Given that only 13 studies included subjective measures of cognitive performance, these effect sizes were not broken down further into cognitive domains. Instead, one main effects meta-analysis was run including all studies assessing subjective cognitive performance and moderator analyses were then conducted.

Bias assessment

To assess publication bias, a funnel plot was created to detect any relationship between study precision and effect size (Fig. S2). To more thoroughly assess for publication bias [39], the trim and fill method was used from the "metafor" package in R. Additionally, a "Failsafe N" calculation was conducted using the Rosenthal approach, in order to estimate the number of additional unpublished studies with an effect size of 0 that would be necessary to render our omnibus results non-significant [40].

Results

Omnibus analysis

The omnibus meta-analysis including all studies across cognitive domains revealed a significant association between insomnia and poorer overall cognitive performance (Hedge's g = −0.24, 95% CI [-0.33, −0.15], p < 0.0001, Fig. S3). The heterogeneity statistic, Cochran's QE, revealed that there was significant residual heterogeneity (QE = 126.05, p < 0.0001).

Objective cognitive performance

To further investigate the association between insomnia and objective cognitive performance, 17 separate meta-analyses were conducted (one for each domain, Fig. 1, Table S5). Significant differences between insomnia and control groups were found for measures of perceptual processes (Hedge's g = −0.24, 95% CI [-0.44, −0.04], $p = 0.017$), alertness (Hedge's g = −0.14, 95% CI [-0.26, −0.02], $p = 0.028$), complex attention (Hedge's g = −0.36, 95% CI [-0.61, −0.12], $p = 0.004$), retention (Hedge's g = −0.30, 95% CI [-0.50, −0.09], $p = 0.004$), and manipulation in working memory (Hedge's g = −0.52, 95% CI [−0.87, −0.18], $p = 0.003$), episodic memory (Hedge's g = −0.29, 95% CI [−0.44, −0.14], $p < 0.001$), and problem solving (Hedge's g = −0.39, 95% CI [−0.66, −0.12], $p = 0.005$). There was a trend for differences in insomnia and control groups for general cognitive functioning (Hedge's g = −0.19, 95% CI [−0.38, 0.01], $p = 0.054$). The results revealed no significant impact of insomnia on psychomotor functions, verbal functions, information processing, selective attention, divided attention, sustained attention, procedural memory, verbal fluency, and cognitive flexibility.

Subjective cognitive performance

To analyze the relationship between subjective cognitive performance and insomnia, one meta-analysis was conducted. This analysis revealed a significant impact of insomnia on subjective cognitive performance (Hedge's g = −0.35, 95% CI [−0.68, −0.03], $p = 0.032$, Fig. 1).

Moderator analyses

Meta-regression analyses revealed no significant moderating effects of gender, age, or study quality for all studies across all cognitive domains in the omnibus analysis (including both subjective and objective measures of cognitive performance). Analysis of the subjective cognitive outcomes alone revealed significant moderation by age (β = 0.04, 95% CI [0.01, 0.07], $p = 0.015$), which accounted for 34.86% of the heterogeneity. Older average sample age was associated with larger effect sizes.

Moderation analyses were also conducted within each of the individual 17 objective cognitive domains. The only significant moderation effects that were observed were that gender moderated the effect of insomnia on executive functions in verbal fluency (β = −0.01, 95% CI [-0.02, −0.01], $p = 0.004$), accounting for 94.27% of the heterogeneity. Samples with higher proportions of females had smaller effect sizes for insomnia on cognitive performance measures of verbal fluency. Moderation analyses were also conducted to assess for impact of type of insomnia measure (clinical or diagnostic assessment vs. any other type of measure) and year published on cognitive performance outcomes, but no significant effects of either on any measures of cognitive performance were observed.

Publication bias

Trim and fill analysis revealed significant asymmetry in effect sizes in the omnibus meta-analysis ($L_0 = 0$, SE = 4.05, $p < 0.001$) indicating an effect of study precision on effect size. Failsafe-N calculation revealed that a value of 1278 ($p < 0.001$) additional studies would be necessary to make the omnibus effect size non-significant.

Discussion

Overall, our findings indicated a significant effect of insomnia on poorer overall cognitive performance. However, there was a large amount of unexplained heterogeneity in this result. When examining the relationship between insomnia and specific cognitive performance domains, we found that insomnia was associated with small to moderate deficits in alertness, complex attention, retention and manipulation in working memory, episodic memory, executive function, and perceptual functions. Insomnia was also associated with moderate deficits in subjective cognitive performance. The moderators we examined (age and gender of the sample, year published, insomnia measure type) did not consistently explain a significant amount of heterogeneity in our results.

Overall, our findings are in alignment with results from the 2012 meta-analysis conducted by Fortier-Brochu et al. [8]. Similar to Fortier-Brochu et al. (2012) [8], we also found that insomnia was associated with deficits in some cognitive domains, but not others. Insomnia was associated with objective deficits in alertness, complex attention, retention and manipulation in working memory, episodic memory, executive function, and perceptual functions, but not psychomotor functions, verbal functions, information processing, selective/divided/sustained attention, procedural memory, verbal fluency, and cognitive flexibility. Elaboration on why deficits in these specific cognitive domains may have been associated with insomnia is provided below.

Alertness and complex attention

Attention is divided into six distinct cognitive domains, yet only alertness and complex attention were found to be significantly associated with insomnia. When assessing complex attention, tasks usually involve different stimuli paired with a distinct response (e.g., stop-signal procedures, switching attention tasks), with the outcome variable being reaction time. This is similar to alertness, which is also traditionally measured as simple reaction time (e.g., psychomotor vigilance task, press the space bar any time you see a letter appear on the screen). One aspect that sets these two domains of attention apart from the rest is the main outcome variable being reaction time. Given this, it is possible that reaction time is a more sensitive measure of cognitive performance. This speculation is consistent with previous research demonstrating that reaction time is a sensitive measure of cognitive performance [41].

Manipulation in working memory

Manipulation in working memory includes tasks such as digit span backwards and 2-back working memory. These types of tasks involve retaining information for a short amount of time and performing a mental task (e.g., reversing the numbers) with that information. Assessments of retention/capacity in working memory measure an individual's ability to retain information in their short-term memory without having to perform any manipulation on that information (e.g., digit span forward, memory and search tasks). The present analysis suggests a significant effect size for the impact of insomnia on both manipulation (Hedges' $g = -0.52$, medium) and retention/capacity (Hedges' $g = -0.30$, moderate) in working memory. Given the difference between the two distinct factors of working memory, it is possible that manipulation in working memory is more dramatically impacted by insomnia as it requires more cognitive ability and the tasks are more cognitively demanding. Despite this, it appears that all domains of working memory are impacted by insomnia, further emphasizing the detrimental impact of insomnia on daytime performance. This finding is consistent with literature investigating the detrimental impact of sleep loss on working memory [42]. Previous research suggests that sleep loss negatively impacts neural processes [43]. Further, objective sleep disturbance has been associated with increased hypothalamic pituitary adrenal axis and sympathetic nervous system activations [44], which has also been positively correlated with deficits in working memory [45,46]. It is possible that these biological mechanisms are playing a role in the impact of insomnia on measures of working memory.

Episodic memory

Episodic memory involves the learning of new material and the ability to recall that material after both short and long delays. Tasks used to assess episodic memory often involve lists or paired words that a respondent is exposed to and instructed to recall at a later time (e.g., verbal paired associates, Williams word memory test). Episodic memory, particularly when asked to recall information after a long delay, is especially susceptible to interference and rapid forgetting. This type of memory is distinct from other types of memory assessed (i.e., working memory) in that it begins to implicate encoding/consolidation and the transferring of information from working memory with activation in the hippocampi to communication with the prefrontal cortex [47]. Previous research has shown that sleep loss impairs episodic memory and leads to memory consolidation deficits when sleep is restricted [48,49]. The current analysis corroborates this research, suggesting episodic memory is significantly associated with insomnia. Given that episodic memory is more complex than other types of short-term memory, it is possible that the increased cognitive demand, and the susceptibility of memory to interference from other stimuli (e.g., stress, competing information, emotion-related interference), is more heavily impacted when individuals are not as well rested.

Problem solving

Problem solving was the only domain of executive function found to be significantly impacted by insomnia in this meta-analysis. Tasks assessing problem solving involve executive functions such as rule learning and spatial planning (e.g., tower test, card sorting tasks). This domain of executive function again appears to be more complex and cognitively challenging than the non-significant domains of flexibility (e.g., Stroop, trail making task) and verbal fluency (e.g., controlled oral word association test). These results again suggest that more intricate, cognitively demanding assessments of cognitive performance may be better suited to detect differences in groups without gross cognitive impairment. Further, the more cognitively challenging domains of functioning may be more impacted by the negative effects of insomnia.

Perceptual functions

Finally, the domain of perceptual functions reflects the participant's cognitive ability to organize and interpret information perceived visually. The current analyses reveal a small effect of insomnia on perceptual functions (Hedge's $g = -0.24$). Assessments of these processes include tests such as the perceptual reasoning index (assessing perceptual fluid reasoning, visual perception and organization, visual-motor coordination, and learning) and critical flicker function (the frequency of a flickering light that appears steady to the observer).

Taken together, the meta-analytic investigation of separate cognitive domains suggests that more complex domains of cognitive performance are impacted by insomnia, whereas less cognitively demanding domains are seemingly resilient to the impact of insomnia, corroborating previous findings [8].

Subjective cognitive performance

Of the studies included in the omnibus meta-analysis, 13 incorporated subjective measures of cognitive performance. Effects within these 13 studies varied widely, and when analyzed together, a significant, moderate-sized effect (Hedge's $g = -0.35$) in subjective cognitive performance by insomnia status was found. A larger effect size for subjective impairment than most measures of objective cognitive performance is not surprising given that those with insomnia may be especially attuned to the impairments in their perceived daytime performance after a poor night's sleep.

Moderator analyses

Interestingly, the moderation analyses only revealed two significant effects: older average sample age was associated with larger effect sizes for the association between insomnia and subjective cognitive performance, and samples with higher proportions of females had smaller effect sizes for the association between insomnia and verbal fluency. Despite these moderating effects being statistically significant, effect sizes were small. Given this and the large number of moderation analyses run, these findings may be spurious and should be interpreted cautiously. Overall, the generally null moderation results suggest that the effects sizes of insomnia on cognitive performance do not consistently vary by study sample age and gender composition, year the study was published, study quality, or type of insomnia measure. While beyond the scope of this study, future research should examine other potential moderators of these relationships (e.g., length and severity of insomnia diagnosis, comorbid conditions). Given that insomnia is commonly comorbid with other disorders (e.g., diabetes, mood disorders, chronic pain) [1,14], future empirical studies should aim to focus on comorbid conditions as a potential moderator of the relationship between insomnia and cognitive performance. It is possible that the presence of comorbid disorders (Table S6) could exacerbate or drive the relationship between insomnia diagnosis and cognitive deficits. Future studies would also benefit from comparing cognitive performance in participants with insomnia and comorbidities and insomnia without comorbidities. Finally, future studies should examine which specific insomnia symptoms (e.g., daytime fatigue, psychological distress, sleep onset latency, sleep efficiency) are most strongly predictive of cognitive performance to inform clinical practice.

Publication bias

Trim and fill analyses revealed an indication of significant publication bias. This finding suggests that studies with smaller sample sizes with null results are less likely to be published than larger studies with null results. Despite this, the Failsafe-N analysis revealed that 1278 studies with null effects would have to be included in order to render our findings insignificant. This demonstrates that, despite the problem of unpublished studies, our findings are robust and should withstand the file-drawer issue. Future studies are encouraged to be transparent about publishing null results and number of individual analyses run in an attempt to minimize the file-drawer problem.

Clinical implications and future directions

This meta-analysis served to critically analyze the current research investigating the relationship between insomnia and cognitive performance. Overall, insomnia was associated with poorer cognitive performance, which suggests the possible utility of treating insomnia to improve cognitive performance. However, it is important to note that these studies were cross-sectional, and it is possible that poor cognitive performance precedes the development of insomnia. Future longitudinal studies should continue to untangle these associations prospectively before more definitive clinical recommendations are made.

Overall, a large amount of residual heterogeneity exists in the relationship between insomnia and cognitive performance. We observed that most studies in our meta-analysis included a wide range of outcomes to represent cognitive performance ($M = 10.61$, $SD = 8.24$). Studies rarely find unequivocal significance across all outcomes. Consequently, it is important to carefully determine which measures are used to assess cognitive performance when analyzing previous research and to carefully govern which measures to use when planning future studies. Further, the time of cognitive testing appeared to vary greatly between studies or often was not reported (Table S1). Time of testing may have a large impact on cognitive performance due to circadian rhythmicity of alertness and fatigue, aging effects (i.e., cognitive decline), and a participants' chronotype (i.e., preferred sleep/wake schedule). Given these considerations, future studies should attempt to more deliberately justify and report time of cognitive assessment. Comparison between studies is made difficult due to the diversity of assessments used and the overall lack of justification for the time of testing and measures chosen to assess cognitive performance [50].

The inconsistent results across cognitive domains in the current meta-analysis also suggest areas for future research: only eight of the 17 cognitive domains were found to be significantly different between those with and without insomnia. This inconsistent relationship could be driven by a multitude of factors, including the 1) categorization and criteria used for insomnia diagnosis, 2) methods used to quantify cognitive performance, and 3) the potential impact of previous night's sleep. Each of these issues is discussed in more detail below:

Insomnia operationalization

It is possible that discrepancies in our findings are due to how insomnia was variably defined across studies. Insomnia is a heterogeneous disorder and previous literature has identified four distinct insomnia definitions [51]: 33% of the population met only one Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) symptom criteria, 9–15% had at least one symptom criteria combined with daytime consequences, 8–18% had at least one symptom criteria combined with sleep dissatisfaction, and 6% of the population met all DSM-IV insomnia diagnosis symptom criteria. Given that prevalence rates can vary from 6% to 33% based solely on the insomnia definition used, it is important to operationalize and standardize the grouping of insomnia for research purposes, as differential definitions can lead to discrepant findings and render outcomes difficult to compare. Within the current meta-analysis, 44% of the studies included failed to use diagnostic criteria as inclusion for their insomnia group. Amongst the studies that did not use diagnostic criteria, a wide range of "insomnia" definitions existed, spanning from a single question about trouble sleeping to DSM-5 diagnosis. This wide range of definitions for insomnia has made the comparison and aggregation of results extremely difficult and largely inconclusive. Future research should strive to use DSM-5 or International Classification of Sleep Disorders, Third Edition (ICSD-3) criteria when studying the implications of insomnia to allow for a clearer understanding of what is being investigated and to aid in the comparisons and future meta-analyses of the relationships. Additionally, insomnia may be better assessed on a continuous dimension of symptoms with multiple phenotypes as opposed to a categorical diagnosis. A large percentage of people suffering from insomnia symptoms and complaints of "insomnia" do not meet DSM-5 criteria for insomnia disorder, indicating that further research is necessary to elucidate the intricacies of the spectrum of complaints in order to differentiate between complaints/symptoms of insomnia and insomnia diagnoses [52]. It is important that these studies also differentially rule out other potential sleep disorders, such as shiftwork sleep disorder, which may be masking as insomnia.

Cognitive performance operationalization

Further, cognitive measure type and quality varied greatly throughout the studies included in the analyses. Measures differed by both sensitivity and content, ranging from assessments such as the Mini-mental state examination (MMSE) to Conners continuous performance test (CPT). Measures like the MMSE are typically used to assess mild to severe cognitive impairment and are often chosen to track the progression of dementia [53] or Parkinson's disease [54]. Given the purpose of these assessments, they are likely not sensitive enough to detect subtle, more situational changes in cognitive performance. They may be subject to a ceiling effect, with almost all participants obtaining close to perfect scores. Going forward, research on cognitive performance and insomnia should aim to utilize more sensitive measures of cognitive performance. Further, it would be useful to develop a standardized battery of cognitive performance that included a measurement of each cognitive domain to create consistency in methods across study and therefore allow for comparison and replication of results (e.g., NIH Toolbox [55], MicroCog [56]).

The potential impact of previous night's sleep

The review of literature also revealed that most studies did not report or assess the impact of previous night's sleep on next day cognitive performance. Despite the fact that many studies reviewed had the opportunity to investigate this relationship (e.g., sleep diaries, actigraphy), none of the eligible studies for the analysis appeared to control for previous night's sleep in analyses or report how it was related to cognitive performance. It is quite possible that discrepant findings and the high amounts of variance in the relationship between insomnia and cognitive performance could be exacerbated by the fact that individuals with insomnia have both good and bad nights of sleep [57]. It could be that after a good night of sleep, cognitive performance is not affected; however, after a bad night of sleep the individual may perform worse than a healthy control. In order to elucidate this relationship, future researchers are encouraged to include previous night's sleep as a factor when assessing sleep's impact on cognitive performance. Within-subjects cross-over designs, where participants with and without insomnia are each assessed before and after sleep deprivation or repeatedly over multiple nights may elucidate both between- and within-person differences in the relationship between insomnia symptoms and cognitive performance. However, this type of design would require cognitive assessments that are resistant to bias caused by repeated measures or practice effects (e.g., equivalent but alternate forms of a measure administered to participants daily, counterbalanced to eliminate sequencing effects).

Conclusion

Overall, this meta-analysis revealed that insomnia is associated with poorer cognitive performance both generally and across multiple specific cognitive domains. However, heterogeneity in this relationship warrants further exploration. In general, our findings replicate results [8] demonstrating that insomnia is associated with poorer retention/capacity and manipulation in working memory, problem solving, and episodic memory. The current meta-analysis further revealed that perceptual functions, alertness, and complex attention were also significantly associated with insomnia. Our results expand the previous study [8] by adding 24 additional studies published since 2012, and examining the impact of moderators on the relationship between insomnia and cognitive performance. Interestingly, average sample age and gender composition, study quality, insomnia measure type, and publication year did not consistently moderate results. This suggests the need to examine other moderators in future research. Given the wide range of findings and the significant levels of heterogeneity between effect sizes of similar cognitive domains, variability in study methods and designs may be driving discrepant results. Future research should aim to utilize the operationalized diagnosis of insomnia when measuring the phenomenon, use more sensitive and appropriate cognitive assessment measures, and assess previous night's sleep. Insomnia is a heterogeneous disorder with different phenotypes presenting unique symptom profiles and should be treated as such when studied. Further development of a more valid measure of insomnia and cognitive performance should improve the rigor of results found and provide sounder clinical recommendations.

Practice points

1. Insomnia is a highly prevalent disorder, warranting further research on implications and treatment of the disorder;
2. Subjective and objective cognitive performance appears to be negatively impacted by insomnia status;
3. Methods of assessing insomnia and cognitive performance vary widely by study;
4. Age, percent female, year of publication, nor insomnia measure consistently moderate the relationship between insomnia and cognitive performance.

Research agenda

1. There is a need for more consistent use of the operationalized diagnosis of insomnia in research;
2. Research should aim to identify a sensitive and comprehensive battery of cognitive performance to be used in order to facilitate comparisons between findings;
3. Further moderators of the relationship between insomnia status and cognitive performance (e.g., comorbid diagnoses, severity and chronicity of insomnia diagnosis) require investigation;
4. Impact of previous night's sleep on next day cognitive performance requires further exploration.

Conflicts of interest

None.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2019.07.008.

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