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Sleep-related attentional and interpretive-bias in insomnia: A systematic review and meta-analysis

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ABSTRACT

Cognitive models of insomnia highlight internal and external cognitive-biases for sleep-related "threat" in maintaining the disorder. This systematic review of the sleep-related attentional and interpretive-bias literature includes meta-analytic calculations of each construct. Searches identified N = 21 attentional-bias and N = 8 interpretive-bias studies meeting the inclusion/exclusion criteria. Seventeen attentional-bias studies compared normal-sleepers and poor-sleepers/insomnia patients. Using a random effects model, meta-analytic data based on standardized mean differences of attentional-bias studies determined the weighted pooled effect size to be moderate at 0.60 (95%CI:0.26–0.93). Likewise, seven of eight interpretive-bias studies involved group comparisons. Meta-analytic data determined the weighted pooled effect size as moderate at .44 (95%CI:0.19–0.69). Considering these outcomes, disorder congruent cognitive-biases appear to be a key feature of insomnia. Despite statistical support, absence of longitudinal data limits causal inference concerning the relative role cognitive-biases in the development and maintenance of insomnia. Methodological factors pertaining to task design, sample and stimuli are discussed in relation to outcome variation. Finally, we discuss the next steps in advancing the understanding of sleep-related biases in insomnia.

Introduction

Insomnia is a prevalent sleep disorder affecting up to 10% of the adult general population, whilst up to 30% of the adult population experience at least some insomnia symptoms at any one time [1]. It is characterised by difficulty with sleep initiation, maintenance and/or early morning awakening, and accompanied by significant impairment to daytime functioning. Insomnia is associated with diminished quality of life [1], physical and mental exhaustion, disturbed mood, concentration and memory, deficits in socioemotional functioning [2], and psychiatric distress [3]. Due to the significant personal burden it imparts, insomnia has long been recognized as a public health concern [4,5].

In psychiatric disorders, an attentional-bias refers to the phenomenon whereby certain populations exhibit excessive attentional allocation towards emotional stimuli related to the symptom experience of their condition compared to non-condition-related information [6]. Similarly, an interpretive-bias involves the tendency to interpret ambiguous stimuli in a manner which is consistent with the concerns of their disorder [7]. Here, the greater tendency to make disorder congruent, rather than a neutral, interpretations of ambiguous stimuli serves as the critical measure of interpretive bias. Cognitive biases are not unique to insomnia and are considered key features of many psychiatric disorders. Indeed, attentional, and interpretive biases play a fundamental role in the psychopathology of anxiety, depression, post-traumatic stress, and substance use disorders [8–11]. For example, individuals with depression are biased towards negative emotional stimuli,

Abbreviations: ABM, Attention Bias Modification; CBTi, Cognitive Behavioural Therapy for Insomnia; DSPS, Delayed Sleep Phase Syndrome; ERP, Event Related Potential; EST, Emotional Stroop Task; IAT, Insomnia Ambiguity Task; PRISMA, Preferred Reporting Items for Systematic Reviews and Meta-analysis.

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interpret neutral stimuli negatively, subsequently reinforcing negative affect and further perpetuating depressive symptomology [10,11]. As such, knowledge of these biases can aid the development of tools to target some of the mechanisms perpetuating negative symptomology, such as by Attention Bias Modification (ABM) paradigms [10].

Coming back to sleep, several theoretical cognitive models have been put forward to explain the mechanisms underlying the development and maintenance of insomnia [12]. Harvey's cognitive model highlights the notion that insomnia is partly maintained by selective attention for sleep-related 'threat' cues which may be internal (i.e., bodily sensations) or external (i.e., environmental noises) [12]. Threats of this nature are considered the product of sleep-specific anxiety, generated by dysfunctional beliefs about sleep and worry about potential consequences of sleep-loss on daytime functioning. Driven by this anxious state, attentional resources are disproportionately allocated to processing sleep-related cues both during the day and the pre-sleep period. Once detected, such cues may be interpreted in an insomnia-consistent manner, cyclically increasing physiological arousal, distress, and negative thoughts concerning sleep and daytime function [12].

Alternatively, Espie's [6] attention intention effort (AIE) pathway proposes that selective attention precedes and leads to sleep intention and sleep effort, culminating in the reduced automaticity of normal sleep. Here, based on Spielman's [13] 3P model of insomnia, sleep-disturbances emerge as a natural response to a significant period of stress where physiological and psychological hyperarousal is induced. Most individuals adapt to these transient bouts of sleep-disturbance, eventually returning to their normal level of sleep. However, according to the AIE model, these disturbances transition to chronic insomnia through the precipitations of three cognitive processes: sleep-related attentional bias; explicit intention to sleep; and behavioural sleep-effort [6]. Like Harvey's model, selective attention is considered to perpetuate the experience of cognitive and somatic sleep-related arousal during the pre-sleep period and throughout the day. As a result, the emergence of compensatory behaviours intended to manually recapture control of sleep serve to paradoxically reduce the homeostatic drive for sleep, maintaining the disorder [6,12].

Attentional biases for disorder consistent words and images are typically determined using experimental reaction-time and free-viewing tasks. These include the dot-probe, flicker, Posner, emotional Stroop, and eye-tracking paradigms [14] (see Fig. 1 for examples of different cognitive tasks and their scoring). In contrast, interpretive bias tasks involve a force choice response to an ambiguous scenario either in a neutral or disorder consistent manner [7]. While a previous narrative review [15] cautiously suggests biased attention for sleep-related threat information to be a likely feature of insomnia based on individual effect sizes, the sleep-related interpretive bias literature remains to be systematically examined. Since this first review, conducted in April 2014, the number of empirical studies examining sleep-related attentional biases have approximately doubled. To that end, the present study sought to systematically review both the sleep-related attentional and interpretive-bias and insomnia literature by providing an evaluation of study quality, synthesis of methodological features and a meta-analytic calculation for each form of bias.

Method

The protocol was pre-registered in the International Prospective Register of Systematic Reviews database (CRD42020207416) and the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) were followed for searching and reporting. Searches and independent screening of titles/abstracts were performed by UA and JS. Reference lists of included studies were screened by UA and JS, with full texts screened for inclusion. Each full text was quality screened by UA, JS and MG. Results were synthesised by UA, MG, NB, BM and JS. UA conducted the meta-analyses.

Literature search strategies

The following databases were searched for articles from all years until September 7, 2020: Web of Science; PubMed; Scopus; PsychINFO; and ScienceDirect. The following Boolean terms were used for searching titles and abstracts: ("sleep" OR "insomnia") AND ("attention bias" OR "attentional-bias" OR "interpretive-bias" OR "interpretation bias" OR "cognitive bias"). Likewise, an updated search (January 15, 2022) was conducted with dates filtered between September 7, 2020 and January 2024.

Study inclusion and exclusion criteria

Where article titles contained "sleep", "insomnia", "attention", "attentional", "interpretation", "interpretive" and/or "bias", and abstract indicated experimental assessment(s) of attentional-bias to sleep-related information, the full article was assessed for inclusion. Conference abstracts, case studies, reviews, opinions, and duplicates were omitted. The inclusion criteria for studies were: i) insomnia or poor-sleeper samples (identified through validated questionnaires); ii) a computerised visual attention allocation/reaction-time based attentional-bias task or paper/computerised interpretive-bias task; adult samples; and iv) successful peer-review. The exclusion criteria involved: i) no computerised/reaction-time based measure of attentional-bias or paper/computerised interpretive-bias task; ii) neuropsychiatric functioning assessment, but not sleep-related cognitive-bias; iii) studies not in English; iv) systematic reviews and editorials; and v) grey literature.

Data extraction and quality assessment

Authors UA, MG and JS assessed the quality of the included studies independently using an adapted version of the Standard Quality Assessment Criteria for Evaluating Primary research papers in a Variety of Fields: A Manual for Quality Scoring of Quantitative studies [16]. This criterion has been used in previous work [17,18] and focuses on the extent to which design, conduct, and analyses minimize errors and biases of quantitative research (see S4). Appraisal involves assessing 14 items on a three-point rating scale. Three items (relating to treatment blinding) were removed for the present review. A global score between 0 and 23 was calculated for each study, enabling study comparisons, where higher scores indicate greater quality. This instrument is included in the supplementary material of this review.

Statistical analyses

Jamovi [19] was used to conduct statistical analyses of the data. A random-effects model was implemented, which assumes that individual studies vary in their average effect sizes, and therefore heterogeneity is to be expected [20]. Although random effects models have less statistical power than fixed effects models, results may be generalized to similar studies not included in the actual analysis [20]. In this analysis, the standardized mean difference (Hedges' adjusted g) was used. Both Cochrane's Q and the I2 statistic were used to assess study heterogeneity. In the former, a significant result is indicative of heterogeneity. In the latter percentages of 25, 50, and 75% indicate low, medium and high

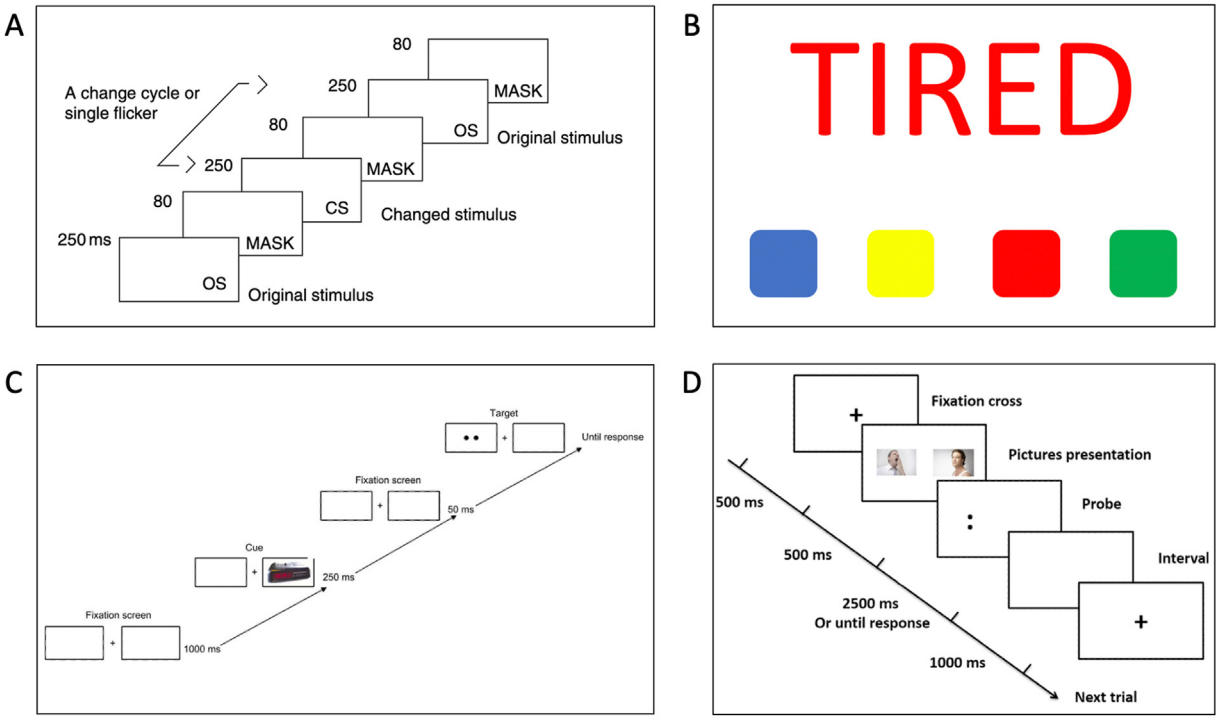


Fig. 1. **[A]** The flicker task examines a concept known as 'induced change blindness' (ICB), where, when a single change has been made to a visual scene, and the method of this change has not been revealed, it is often more difficult to ascertain this change than expected [9]. In essence, the flicker task is similar to a 'spot the difference' task, where a change is made to pictorial stimuli, and the participant is required to detect this change. Further, a single part of pictorial stimuli is altered between sequentially recurrent brief presentations (known as flickers) until the change is identified. The number of flickers surpassed before the change has been identified acts as the measure of response latency. Moreover, faster response latencies are considered to suggest an increased attention bias. [Example trial from 28]. **[B]** Emotional Stroop Task: The EST involves presenting participants with neutral and threatening words in different colours. Participants are required to press a correspondingly coloured response key as quickly as possible. Longer response latencies to threatening words are considered to suggest an increased attention bias (or Stroop interference). Due to the content of the threatening word expending attentional resources, performance on the task is subsequently impaired. Higher (positive) interference index scores indicate attentional bias towards emotionally salient material. [Example trial created by author]. **[C]** The participant is instructed to maintain fixation on a central cross on a computer screen. To the left and right of the cross are two boxes. A cue (e.g. an alarm clock) is presented on the screen. Then, the cue is removed and a target stimulus (usually a shape) appears in either the left or right box. In valid trials, the stimulus is presented in the same box as the target; in invalid trials, the stimulus appears in the opposite box of the target. Participants respond to the target by pressing a key on the keyboard as quickly as possible. A valid trial provides a measure of attentional engagement or vigilance, whereas an invalid trial provides a measure of attentional disengagement or avoidance. Fast RTs on valid trials suggest enhanced engagement with the cue stimulus, whereas longer RTs on invalid trials indicate delayed disengagement from the stimulus. [Example trial from 33]. **[D]** Dot-probe task trial. Trials initially start with a fixation crossing the middle of the computer screen. Pairs of emotional and neutral stimuli (words or images) are then presented horizontally. After the words disappear a dot-probe (large dot) subsequently appeared either on the right or left position. This remains on the screen until a keyboard response is made or the trial times-out. Participants are required to press a corresponding key, indicating the position of the probe, as quickly and as accurately as possible. After an interval, the next trial begins. The vigilance index is calculated by subtracting the mean reaction time for sleep-related stimuli from the mean reaction time for neutral stimuli. In contrast, the mean reaction time for neutral trials were subtracted from the mean reaction time for trials where the dots replaced neutral stimuli in the presence of sleep-related stimuli to calculate the disengagement index. [Example from 24]. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

heterogeneity [16]. A forest plot of overall effect sizes against the standard errors for each study are presented. A Z test determined the significance of the pooled *d*.

Results

Results of the literature review

The initial database search yielded 3693 potentially relevant studies (Web of Science = 156, PubMed = 73, SCOPUS = 139, PsychINFO = 2271, and ScienceDirect = 1054). After reading the titles and abstracts, and excluding duplicates, $N = 39$ articles were accessed in full and considered for inclusion. Examination of full texts led to exclusion of 11 studies. Following the updated search in January 2022 yielding 585 potentially relevant studies, an additional study was included. The final sample consisted of $N = 29$ studies fulfilling the inclusion criteria (see Fig. 2). Twenty-one of these studies examined sleep-related attentional-bias, whereas 8 examined interpretive-bias. $N = 17$ of 21 attentional-bias studies included a comparison between poor-sleepers or insomnia patients and normal-sleepers. $N = 7$ of 8 interpretive-bias studies included group comparison. (see S5 for quality ratings; S1 and S2 for comprehensive summaries).

Quality assessment

Quality scores ranged from 16 to 22 for attentional-bias studies (M=20.57) and 20–22 for interpretive-bias studies (M=20.25). As such, most of the available evidence appears to be of moderate quality. All studies ($N = 29$) relied on cross-sectional data, preventing directional causality assessment. Most provided a detailed hypothesis ($N = 19$), few conducted a power calculation or indicated whether sufficient power was achieved ($N = 4$).

Sleep-related attentional-bias

Attentional-bias tasks and stimuli

Of $N = 21$ studies examining sleep-related attentional-bias, 18 adopted a single paradigm using the: emotional Stroop task (n = 5) (EST; 21–26), dot-probe (n = 6) [28–33], induced change blindness

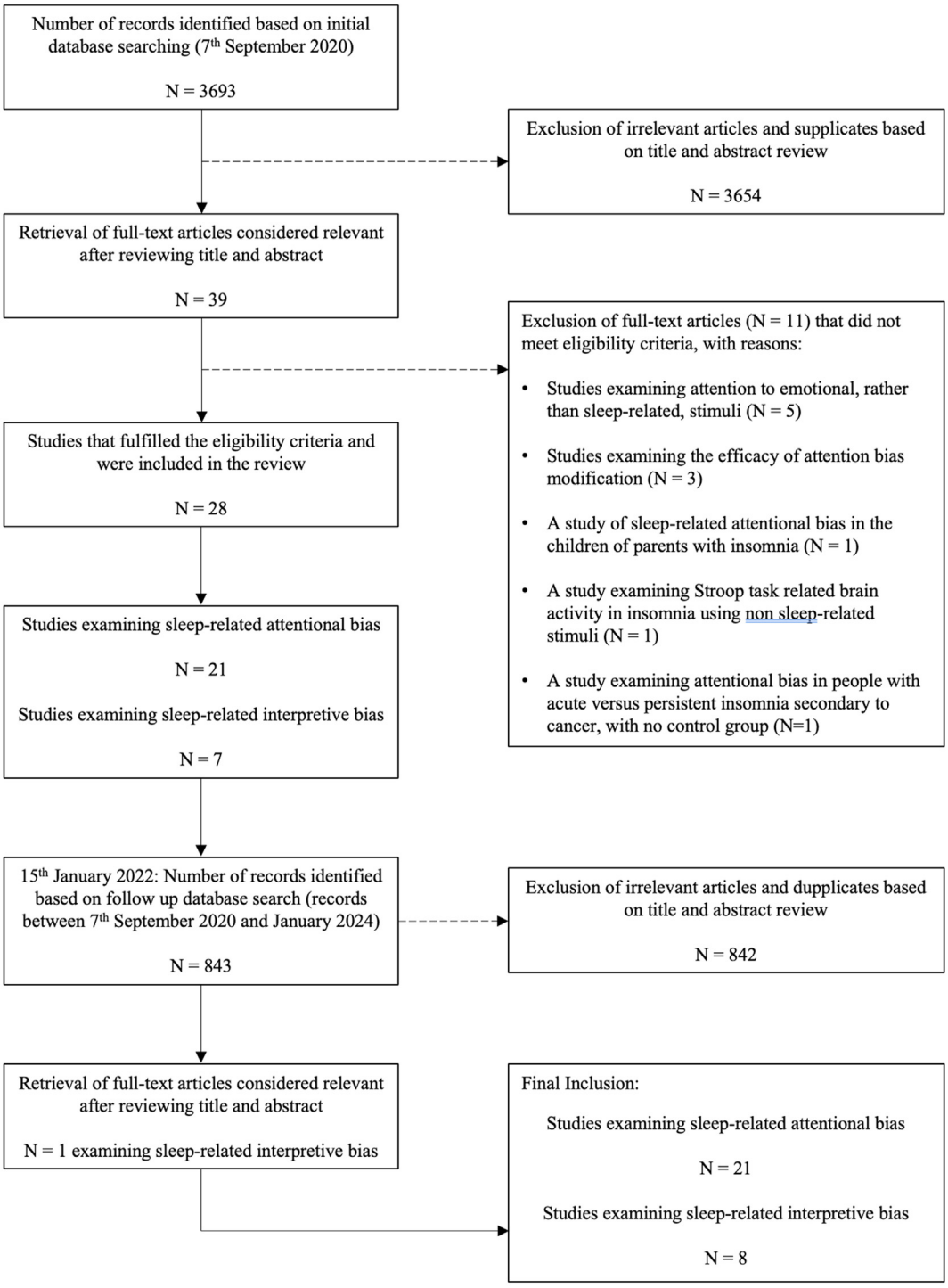


Fig. 2. Flowchart presenting the literature search and study selection strategies.

(flicker) paradigm (n = 2) [23–34], visual attention using eye-tracking (n = 3) [35–37], Posner paradigm (n = 1) [38], Single-Target Implicit Association Test (n = 1) [39], and spatial filtering following a visual probe task (n = 1) [40]. Four combined two attentional-bias tasks: two studies used the EST and a mixed modality (visual–auditory) task [25,26], one study used both the emotional Stroop and dot-probe task [31], another combined dot-probe and the N-back task [32].

Stimuli between tasks varied (e.g., words, pictures). Ten studies used words, ten used pictorial stimuli, and two used both [25,26]. Some studies [21-22,24-26,31-31] reported matching words for either length, number of syllables, or use frequency. Barclay and Ellis [21] selected non-affective sleep-related words, validation details were not specified. Several used sleep-related words [21–26,30,31,41] that were developed from qualitative research on pre-sleep thought content in poor-sleepers [42]. Zhou et al. [27]

translated words into Chinese. Two studies failed to document the selection process [23,41].

Spiegelhalder et al. [23,25,26] used non-validated pictures of bedroom-scenes. Jansson-Fröjmark et al. [29] selected images from the Internet based on: likelihood of inducing valence and arousal, matching of situations, age and gender in each pair, and qualitative features (e.g., lighting/background). Zheng et al. [39] replicated this procedure. In studies using the flicker paradigm [23,24], sleep-related items were based on judgments of people listing objects related to sleep-initiation. Subsequently, the most frequent objects were imaged. Woods et al. [38] used alarm-clock images (displaying times). Takano et al. [32] used sleep-related and garden-related images adapted from Jones et al. [33]. Beattie et al. [36] used bedroom, living-room and kitchen scenes. Finally, Akram et al. [28,35] used sleep-related facial stimuli depicting tiredness as pictorial stimuli.

Meta-analysis calculations of attentional-bias

The meta-analysis analysis was conducted using the MAJOR plugin for the Jamovi [19] statistical analysis package. Specifically, the standardized mean difference of attentional-bias scores was the outcome measure (see Table .1). A random-effects model was fitted to the data, and heterogeneity (i.e., T^2), was estimated using the Hedges' estimator [19]. The Q-test for heterogeneity and the I^2 statistic was also reported. Where heterogeneity was detected (i.e., $T^2 > 0$, regardless of the Q-test outcomes), a prediction interval for true outcomes were provided. Tests and confidence intervals were computed using the Knapp and Hartung method [20]. Studentized residuals and Cook's distances examined whether studies may be outliers and/or influential in the context of the model. Studies with a studentized residual larger than the 100 x (1−0.05/[2 X k])th percentile of a standard normal distribution were considered potential outliers (i.e., using a Bonferroni correction with two-sided $\alpha = 0.05$ for k studies included in the meta-analysis). Studies with a Cook's distance larger than the median plus six times the interquartile range of distances were considered influential. The rank correlation and regression test (standard error as predictor) evaluated funnel plot asymmetry.

Overall, $k = 17$ studies (insomnia/poor-sleeper $N = 447$, controls $N = 475$), and thirty-five variables were analysed. Standardized mean differences ranged from −0.893-3.565, with most being positive (71%). The estimated average standardized mean difference based on the random-effects model was: = 0.60 (95% CI: 0.26−0.93). Therefore, the average outcome differed significantly from zero ($t(34) = 3.63$, $p < .001$). According to the Q-test, the true outcomes appear heterogeneous ($Q(34) = 228.07$, $p < .001$, $T^2 = 0.91$, $I^2 = 90.70\%$). A 95% prediction interval for the true outcomes is given by −1.370-2.563. Hence, although average outcome are positive, in some studies the true outcome may be negative (e.g., where attentional disengagement was evidenced). Examination of the studentized residuals revealed no studies with a value larger than ±3.19 and thus no indication of outliers. According to the Cook's distances, two studies [26,41] could be overly influential. The regression test indicated funnel plot asymmetry ($p = .0003$) but not the rank correlation test ($p = .112$: see Fig. 3) (see Fig. 4).

Summary of attentional-bias outcomes

This section overviews each study by task (see Fig. 1 for methodological information).

Dot-probe task

MacMahon and colleagues [30] compared attentional-bias outcomes between individuals with primary insomnia, delayed sleep phase syndrome (DSPS) and normal-sleepers. Subjects with DSPS acted as a second control group, accounting for physiological sleep onset difficulties unattributed to cognitive processes. Insomnia participants displayed greater vigilance for sleep-related (relative to neutral) words compared to those with DSPS and normal-sleepers. Using the same task with sleep-related and control images and neutral control images, two studies found no sleep interference differences between controls and insomnia patients [30,31].

Jansson-Frömark and colleagues [29] used sleep-related images portraying fatigue/malaise and neutral images to examine attentional-bias indices (vigilance vs disengagement) in insomnia and good-sleepers. Rather than increased vigilance, insomnia was characterised by disengagement difficulties whilst observing sleep-related images, compared to normal-sleepers. The authors consider stimuli pertaining to daytime fatigue/malaise rather than nighttime cues (which may trigger conditioned arousal) to account for the lack of vigilance effect. Akram and colleagues [28] examined whether individuals with insomnia exhibit an attentional-bias for sleep-specific (vs. neutral) faces depicting tiredness. Here, individuals with insomnia displayed decreased vigilance towards sleep-related cues compared with normal-sleepers. Like [29], insomnia participants struggled to disengage attention away from sleep-related images.

Zheng and colleagues [39] determined greater attentional-bias following a negatively induced mood state (recall of poor-sleep) in those with insomnia, relative to a neutral control mood state (reading recall). Following the negative mood induction, a general bias (i.e., regardless of image content) emerged after observing generally threatening and sleep-related images amongst those in the insomnia group.

Emotional stroop task

Lundh and colleagues [22] were the first to utilise the EST to examine attentional-bias in insomnia. Here, both insomnia patients and controls were quicker to respond to sleep-related, relative to, threatening and neutral words. However, critical measure of attentional-bias was not calculated (i.e., Stroop interference index). Therefore, Stroop interference was calculated for the current review, by subtracting reaction times for neutral words from sleep-related words, where greater scores indicate a sleep-related attentional-bias. We revealed that insomnia participants evidenced a greater degree of sleep-related attentional-bias relative to controls (4.80 ± 03.38 vs. 3.85 ± 0.65, $d = 0.35$) [22].

Spiegelhalder and colleagues [25] used the EST and mixed modality paradigm to examine attention bias amongst good-sleepers and insomnia patients. Sleep-experts (sleep disorder clinic staff) also participated to control for frequency of concept usage. Whilst sleep-interference failed to differ between insomnia patients and controls, greater interference emerged in insomnia compared to sleep-experts. No differences in attentional-bias were observed on the mixed modality task. The authors consider attention bias a consequence of altered emotional, cognitive or procedural processing rather than frequency of concept use. In a follow-up [23], the authors observed greater sleep-related interference amongst insomnia patients compared to controls. In another study, poor-sleep-quality and sleepiness were associated with a bias for sleep-related words [26]. Here, an interaction between sleep-quality and sleepiness determined reduced attentional-bias when: poor-sleep was related to increased sleepiness; and greater sleep-quality was associated with reduced sleepiness. These outcomes support the Attention-Intention-Effort (AIE) model of insomnia [6], whereby physiological craving for sleep induces sleep-related attentional-bias. Additionally, experiencing sleepiness may comfort poor-sleepers, who typically perceive increased arousal as threat. This may explain greater EST performance in the co-occurrence of poor-sleep-quality and increased sleepiness [26].

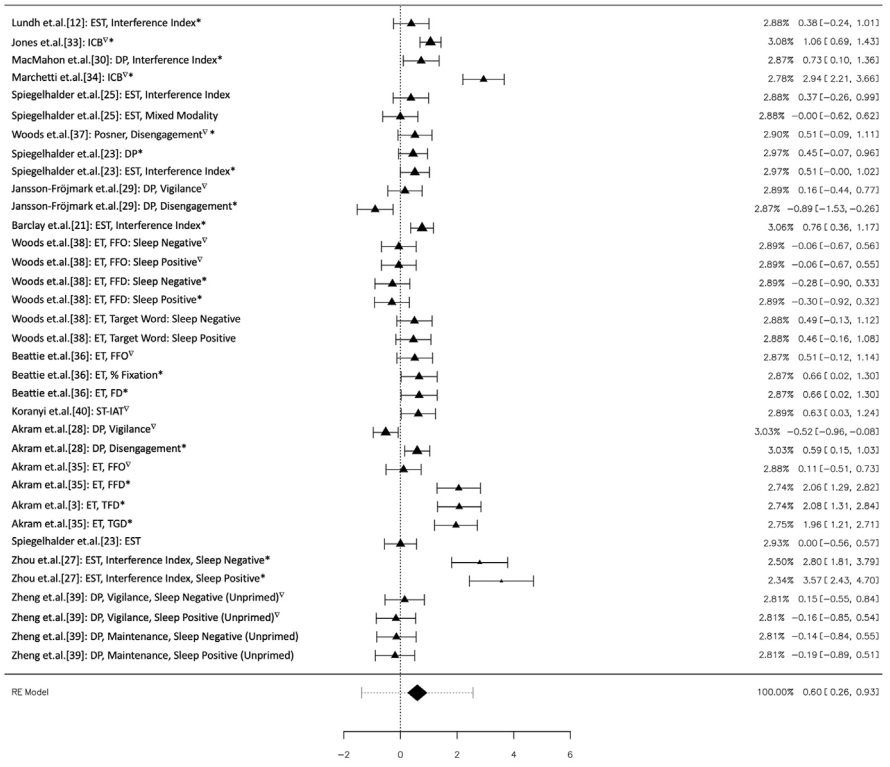
Table 1
Forest plot of overall effect sizes for attentional-bias studies.

Forest plot of overall effect sizes for attentional-bias studies.

	Insomnia/Poor-sleepers		Control Groups		Cohens *d*
	Mean	Total N	Mean	Total N	
Lundh et.al.[22]: EST, Interference Index*	4.80±3.38	20	3.85±0.65	20	0.35
Jones et.al.[33]: ICB$^{\nabla}$*	-14.5±8.5	64	-23.1±7.6	64	1.07
MacMahon et.al.[30]: DP, Interference Index*	3.9±9.4	21	-2.5±7.6	20	0.75
Marchetti et.al.[34]: ICB$^{\nabla}$*	4.7±2.1	30	12.4±3.0	30	2.97
Spiegelhalder et.al.[25]: EST, Interference Index	3.8±15.4	20	-1.9±14.8	20	0.38
Spiegelhalder et.al.[25]: Mixed Modality	-4.3±36.3	-	-4.2±23.1	-	0.00
Woods et.al.[37]: Posner, Disengagement$^{\nabla}$ *	523±130	22	584±102	22	0.52
Spiegelhalder et.al.[23]: DP*	8.9±30.5	30	7.6±41.6	30	0.04
Spiegelhalder et.al.[23]: EST, Interference Index*	−0.6±19.7	-	−11.4±22	-	0.52
Jansson-Fröjmark et.al.[29]: DP, Vigilance$^{\nabla}$	4.5±39.9	21	0.6±18.3	21	0.13
Jansson-Fröjmark et.al.[29]: DP, Disengagement*	-20.8±38.3	-	9.5±27.4	-	0.91
Barclay et.al.[21]: EST, Interference Index*	11.42±0.48	42	0.19±18.69	65	0.88
Woods et.al.[38]: ET, FFO: Sleep Negative$^{\nabla}$	261±358	21	240±362	20	0.06
Woods et.al.[38]: ET, FFO: Sleep Positive$^{\nabla}$	256±348	-	236±331	-	0.06
Woods et.al.[38]: ET, FFD: Sleep Negative*	1662±928	-	1927±909	-	0.29
Woods et.al.[38]: ET, FFD: Sleep Positive*	1646±943	-	1932±922	-	0.31
Woods et.al.[38]: ET, Target Word: Sleep Negative	2039±1051	-	1627±454	-	0.51
Woods et.al.[38]: ET, Target Word: Sleep Positive	1816±568	-	1586±393	-	0.47
Beattie et.al.[36]: ET, FFO$^{\nabla}$	1131±340	20	1326±411	20	0.52
Beattie et.al.[36]: ET, % Fixation*	19.4±6.2	-	16.2±2.6	-	0.67
Beattie et.al.[36]: ET, FD*	698±274	-	549±150	-	0.67
Koranyi et.al.[40]: ST-IAT$^{\nabla}$	0.13±0.20	22	0.29±0.29	22	0.64
Akram et.al.[28]: DP, Vigilance$^{\nabla}$	-27.6±67.0	41	-2.41±10.66	41	0.53
Akram et.al.[28]: DP, Disengagement*	30.9±73.9	-	0.78±12.79	-	0.57
Akram et.al.[35]: ET, FFO$^{\nabla}$	680±62	20	687±62	20	0.11
Akram et.al.[35]: ET, FFD*	121±10	-	100±10	-	2.10
Akram et.al.[35]: ET, TFD*	739±93	-	542±93	-	2.12
Akram et.al.[35]: ET, TGD*	788±97	-	594±97	-	2.00
Spiegelhalder et.al.[23]: EST	4.6±20.4	20	4.5±28.7	30	0.00
Zhou et.al.[27]: EST, Interference Index, Sleep Negative*	11.69±6.86	16	-7.72±6.64	15	2.88
Zhou et.al.[27]: EST, Interference Index, Sleep Positive*	12.65±6.70	-	-11.44±6.45	-	3.66
Zheng et.al.[39]: DP, Vigilance, Sleep Negative (Unprimed)$^{\nabla}$	12.79±68.35	17	21.30±35.33	15	0.16
Zheng et.al.[39]: DP, Vigilance, Sleep Positive (Unprimed)$^{\nabla}$	13.32±39.82	-	6.95±38.19	-	0.16
Zheng et.al.[39]: DP, Maintenance, Sleep Negative (Unprimed)	-8.97±65.98	-	-0.94±39.80	-	0.15
Zheng et.al.[39]: DP, Maintenance, Sleep Positive (Unprimed)	-7.22±55.01	-	1.23±23.63	-	0.20

Heterogeneity: Tau^2=0.91; H^2=10.76, df=34 (P=0.001); I^2=91%
Test for overall effect: Z=3.63 (P < 0.001)

Note: ∇=Reverse scored, *=Significant difference



Note: DP, Dot-probe; EST, Emotional Strop test; ET, Eye-Tracking; ICB, Induced Change Blindness; FFO, First Fixation Onset; FFD, First Fixation Duration; TFG, Total Gaze Duration; TFD, Total Fixation Duration; TGD, Total Gaze Duration; ST-IAT, Single Target Implicit Association Test.

Barclay and Ellis [21] compared sleep interference between poor and good-sleepers using non-affective sleep-related words, neutral words and non-specific threat words. Rather than examining attentional-bias scores, mean reaction times of word type were calculated. No differences emerged when examining response times to sleep-related words. However, within-group analysis in

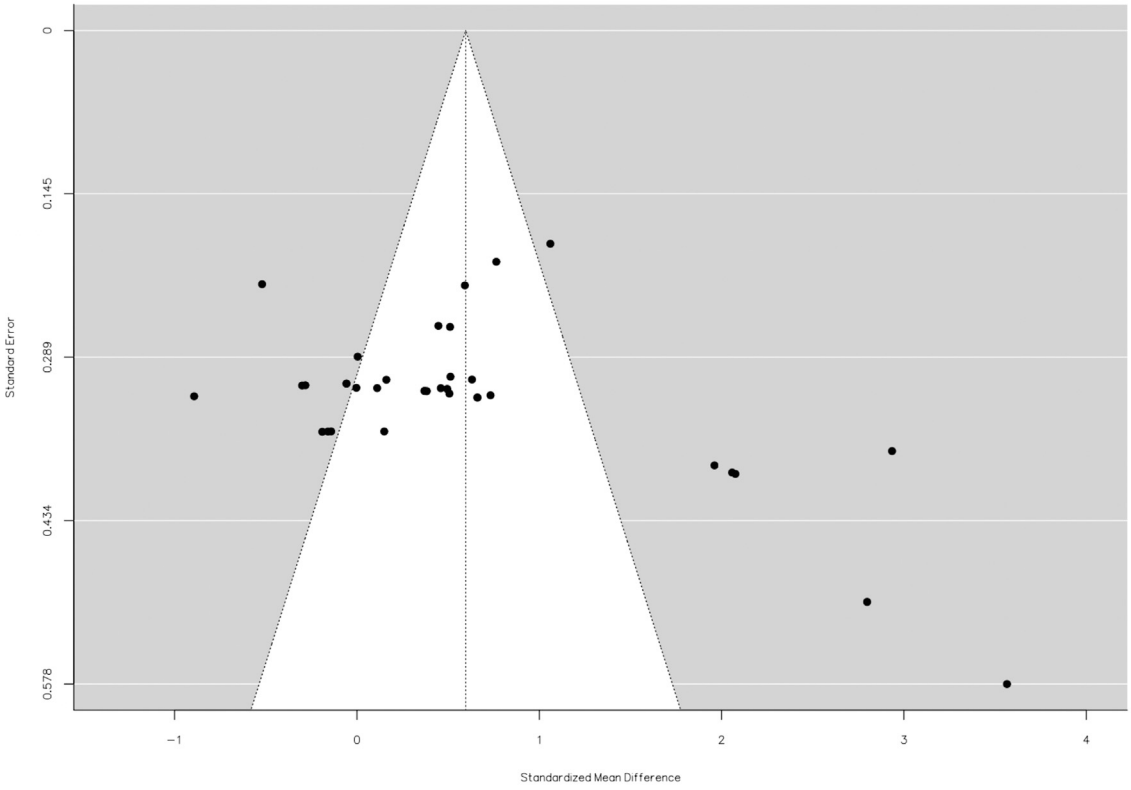


Fig. 3. Funnel plot of meta-analytic effect sizes for sleep-related attentional bias. Vertical line on pooled effects of mean standardized difference.

poor-sleepers found increased response latencies to sleep-related compared to non-specific threat words. Here, personally relevant (sleep-related) threats hampered performance, whereas non-specific threats accelerated performance. The authors suggest that sleep might have been particularly salient for both groups given that the experiment was conducted in the evening and that poor-sleepers may be consumed by sleep specific stimuli, yet highly adapted to generally threatening cues [21]. As the critical measure of attentional-bias was (i.e., Interference), this was calculated for the current review. The outcomes indicate a greater degree of sleep-related attentional-bias relative to controls (11.42 ± 0.48 vs. 0.19 ± 18.69,$d = 0.88$).

Two studies examined the relationship between brain reactivity and selective attention for sleep-related words in insomnia. Zhou and colleagues [27] used the EST whilst recording event-related potentials (ERP) in participants with insomnia disorder and good-sleepers to examine attentional-bias towards sleep-negative, sleep-positive and sleep-unrelated neutral words. Here, compared to good-sleepers, the insomnia group elicited greater interference for sleep-positive, and marginally significant ($p = .051$) interference effect for sleep-negative words. Moreover, ERP data in the insomnia group found sleep-negative words activated higher amplitudes of P1 and N1 components relative to sleep-positive and neutral control words. These results further evidence the attentional-bias in insomnia, and uniquely indicate enhanced selection and processing of sleep-related information early in the attentional system. Spiegelhalder and colleagues [23] used Functional Magnetic Resonance Imaging to examine brain reactivity to sleep-related words in insomnia patients and good-sleepers. Here, patients failed to differ from controls in brain reactivity to sleep-related words. Similarly, EST completion outside the scanner evidenced no group differences in attentional-bias.

Flicker task

Jones and colleagues [33] used the flicker task to examine attentional-bias towards bedroom objects in good, moderate, and poor-sleepers using three image sets: the original stimulus (OS), sleep-related (CS−S) and neutral changed stimulus (CS−N). The CS-S involved removing slippers, whilst the CS-N removed a pair of gloves. Compared with good-sleepers, poor-sleepers displayed quicker change detection latencies for sleep-related relative to neutral changes, demonstrating an attention bias. Likewise, moderate sleepers were also quicker than good-sleepers. When replicated [34], insomnia participants identified sleep-related changes faster than DSPS and good-sleeper groups, and neutral stimuli changes.

Eye-tracking

Advancing the literature, several studies examined gaze-behaviour while observing sleep-related stimuli [35–37]. Woods and colleagues [37] first compared the gaze behaviour of good-sleepers and individuals with insomnia observing sleep-positive, sleep-negative, and neutral words. Regardless of word type, insomnia participants were slower to fixate on target words and remained fixated for less time relative to good-sleepers. Individuals with insomnia discriminated between target and distractor words more slowly than good-sleepers. Both groups fixated longer on positive and negative sleep-related words compared to neutral, an effect more prominent in insomnia. Possibly, these outcomes reflect a general impairment in discriminating and maintaining

attention. Expanding on word stimuli, Beattie and colleagues [36] compared visual attention of normal-sleepers and individuals with insomnia-symptoms by recording eye-movements during free-viewing of bedroom scenes. Groups equally located bed regions, and number of fixations made during each trial. However, the insomnia group fixated more frequently on bed regions, maintaining their gaze for longer than controls [36]. Finally, when presenting sleep-neutral face pairs, individuals with insomnia spend more time fixating on and observing sleep-related (i.e., tired) rather than neutral faces, compared to normal-sleepers [35]. These outcomes support the notion of attentional-bias for faces depicting tiredness in insomnia. (see S3 for variable definitions)

Other methodologies

Using a Posner paradigm, Woods and colleagues [38] examined differences between individuals with insomnia and good-sleepers in vigilance and disengagement towards alarm clock times. Compared with controls, insomnia participants evidenced disengagement difficulties on invalid trials (stimulus opposite target). Whilst no differences in valid trials (stimulus presented with target) emerged, those with insomnia were slower on invalid relative to valid trials. Alarm clock salience possibly captures attention in insomnia, in line with sleep-associated monitoring of environmental cues highlighted in cognitive models of insomnia [6,12]. In another study, during fMRI recordings, insomnia patients evidenced increased amygdala activity whilst viewing images of people lying awake and visibly frustrated in bed at night, compared to good-sleepers [43]. This indicates possible sleep-related reactivity and, by extension, sleep-related attentional-bias, in insomnia.

Another study employed the single-target implicit association test where participants indicated the appropriate affective valence of positive and negative words, whilst classifying sleep-related words (e.g., bed, pillow, blanket) into a target category of 'bed' [40]. Here, insomnia patients revealed more negative affective response towards sleep-related words compared to good-sleepers. Giganti and colleagues [41] used a visual prime task to determine whether students with and without insomnia differed in vocal categorisation (i.e., "old" or "new") of neutral and sleep-related images. Whilst implicit memory was unaffected by sleep, responses were influenced by stimuli type. Independent of priming, insomnia participants recognized sleep-related images at lower spatial frequencies (indicating an attentional-bias) relative to controls. According to the authors, these studies suggest attentional-bias in insomnia may be driven by a state of cognitive hyper-arousal as described by cognitive models [6,12].

Using the n-back task, Takano and colleagues [32] examined subjective sleep-quality and difficulties in working memory for sleep-related stimuli, a potential mechanism underlying pre-sleep cognitive arousal. Specifically, a general population sample determined the content of sequential 1-back and 2-back image presentations as either sleep-related or non-sleep-related. Sleep-quality was not related to sleep-interference on each task. Whilst cognitive and somatic arousal were unrelated to sleep-interference on the 1-back task, pre-sleep arousal predicted interference from sleep-related stimuli. Here, pre-sleep arousal may be accompanied by greater efficiency in processing sleep-related information alongside less distraction by a sleep-related distractor when processing non-sleep-related information.

Sleep-related interpretive-bias

Interpretive-bias tasks and stimuli

Five of 8 studies examining interpretive-bias in insomnia used the Insomnia Ambiguity Task (IAT), developed by Ref. [7]. Here, ambiguous sentences are followed by two possible interpretations, one insomnia-consistent and another insomnia-inconsistent. For example, *Sam knew how long it would take to fall asleep: slow* (insomnia-consistent), or *fast* (insomnia-inconsistent). Participants choose between the polarised endings for each sentence. Additional studies involved: individually programmed face-morph tasks for each participant to examine how individuals with insomnia and controls interpret their own facially expressed tiredness [44]; resolving scenarios describing the consequences of poor-sleep, and non-sleep-related activities in either a benign or negative manner [45–48]; and choosing between answering sleep-related or eating-related questions [49].

Effect size calculations for interpretive-bias studies

The same methodological approach used for attentional-bias effect size was used to determine the interpretive-bias calculation (see Table 2).

Overall, $k = 7$ studies were analysed. The observed standardized mean differences ranged from 0.149 to 0.834, all positive (100%). Estimated average standardized mean differences based on the random-effects model were: = 0.44 (95% CI: 0.19–0.69). Therefore, average outcomes differed significantly from zero ($t(6) = 4.331$,p = .005). From the Q-test, no significant heterogeneity in the true outcomes emerged ($Q(6) = 9.85$, $p = .130$,$I^2 = 0.01$,$I^2 = 18.60\%$). A 95% prediction interval for the true outcomes is given by 0.09–0.80. Whilst some heterogeneity may emerge, the true outcomes were in the same direction as the estimated average outcome. Examination of studentized residuals revealed one study [47] with a value above±2.69 which may be an outlier. Based on Cook's distances, this study could be overly influential. Neither the rank correlation nor regression test indicated funnel plot asymmetry ($p = .773$ and $p = .416$, respectively). See Fig. 4 for funnel plot.

Summary of interpretive-bias outcomes

An interpretive-bias involves increased threat-congruent inferences in response to ambiguous and open-ended situations [7], where disorder congruent, over neutral, interpretations of ambiguous stimuli is the critical measure of interpretive-bias [7]. Increasingly, studies have confirmed sleep-related interpretive-biases amongst poor-sleepers and individuals with insomnia-symptoms using the IAT [7,44–50].

Ree and Harvey [7] first examined sleep-related interpretive-biases in students with and without insomnia. Participants read insomnia and anxiety (general threat) related ambiguous sentences and subsequently chose between insomnia consistent, general threat consistent and general threat inconsistent words. Whilst no bias emerged, increased sleepiness predicted a general bias for threat. Further research compared poor and normal-sleepers in their responses to a paper-based IAT [45]. Here, poor-sleepers interpreted ambiguous situations in a threat-related manner, whether insomnia or anxiety related. These outcomes have been partially replicated [45–48]. In poor and normal-sleeping students, one study examined priming effects of sleep-related questionnaires assessments in accentuating interpretive-bias outcomes [46]. Here, participants completed the IAT either before or after completing a series of sleep-related questionnaires. Irrespective of priming, poor-sleepers interpreted ambiguous sentences as insomnia-consistent rather than insomnia inconsistent. Overall, primed subjects endorsed more insomnia-consistent interpretations, an effect more prominent amongst poor relative to normal-sleepers. Poor-sleepers may be more sensitive to sleep-related information, possibly increasing a pre-existing tendency to interpret ambiguous scenarios as insomnia-consistent.

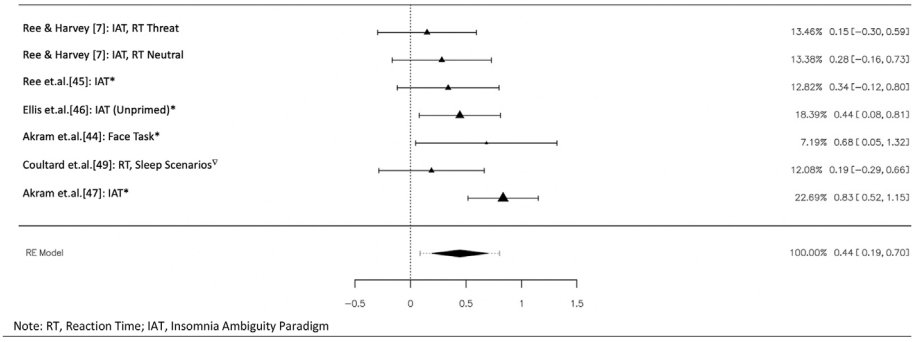
Courtauld and colleagues [49] examined biased expectations amongst individuals experiencing insomnia-symptoms and

Table 2
Forest plot of overall effect sizes interpretative-bias studies.

Forest plot of overall effect sizes interpretative-bias studies.

	Insomnia/Poor-sleepers		Control Groups		Cohen's *d*
	M	Total N	*M*	Total N	
Ree & Harvey [7]: IAT, RT Threat	66±71	40	54±88	38	0.15
Ree & Harvey [7]: IAT, RT Neutral	77±62	40	57±78	38	0.28
Ree et.al.[45]: IAT*	14.25±4.77	34	12.69±4.36	41	0.34
Ellis et.al.[46]: IAT (Unprimed)*	14.52±3.48	31	12.90±3.76	29	0.45
Akram et.al.[44]: Face Task*	28.75±79.70	20	-19.80±57.71	20	0.70
Coultard et.al.[49]: RT, Sleep Scenarios$^{\nabla}$	2673±1061	30	2976±1883	40	0.19
Akram et.al.[47]: IAT*	17.63±4.33	67	13.69±4.92	109	0.85

Heterogeneity: Tau^2=0.01; H^2=1.23, df=6 (P=0.13); I^2=19%
Note: ∇=Reverse scored, *=Significant difference
Test for overall effect: Z=4.33 (P < 0.005)



Note: RT, Reaction Time; IAT, Insomnia Ambiguity Paradigm

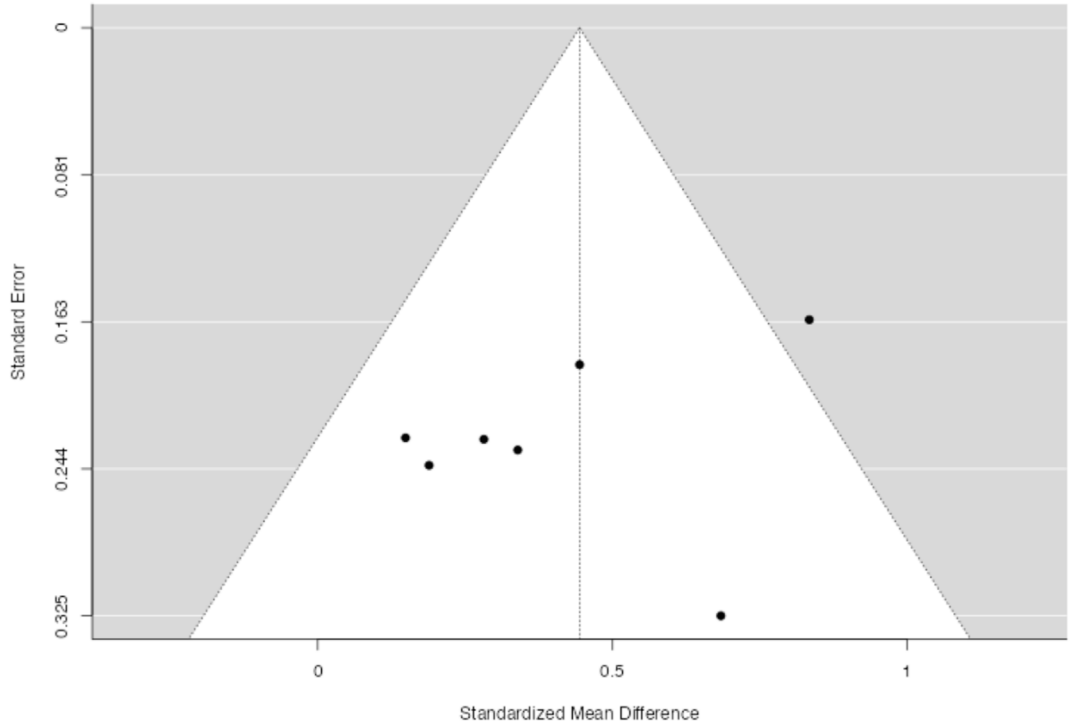


Fig. 4. Funnel plot of met-analytic effect sizes for sleep-interpretive bias. Vertical line on pooled effects of mean standardized difference.

controls, who resolved scenarios describing consequences of poor-sleep, and non-sleep-related activities in either a benign or negative manner. Response latencies provided an index of expectancy bias. Individuals presenting insomnia-symptoms were faster to resolve sleep-related scenarios as negative, over benign, compared with controls. However, groups failed to differ when resolving non-sleep-related scenarios. Using a pay-per-view task, Takano and colleagues [50] examined whether poor-sleep was related to preference for sleep-related topics. Specifically, a general population sample opted to answer sleep or eating-related questions. Choices were associated with a variable economic reward where participants would occasionally face conflict between economic gain and intrinsic preference to discuss sleep. Poor-sleep-quality was associated with forgoing greater economic reward to answer sleep-related (opposed to eating-related) questions. Despite negative consequences, poor-sleepers appear to voluntarily engage in sleep-related thinking. This motivation appears consistent with the AIE

model [6], and may explain why people continue to worry about their sleep (lessness).

Akram et al. [44] examined whether individuals with insomnia misperceive facial attributes of tiredness in a disorder-consistent manner. Compared with normal-sleepers, individuals with insomnia disorder interpreted their own face as appearing more tired than they physically were, confirming symptoms of their disorder. Likewise, questionnaire studies find insomnia-symptoms are related to interpretations of cutaneous features in a manner consistent with the presence of a sleep-deficit. Relatedly, the association between insomnia-symptoms and perception of cutaneous features was mediated by greater reports of sleep-related monitoring on awakening [51].

Possible mediational factors underlying disorder-consistent processing of sleep-related information in insomnia have recently been experimentally examined [48,49]. Gerlach and colleagues [44] evidenced a relationship between pre-sleep worry and poor-sleep-quality with sleep-related interpretive bias outcomes using the IAT. Interestingly, regression analyses suggested these outcomes were mediated by trait anxiety but not objective sleep-continuity. Recent work [47] examined possible mechanisms influencing sleep-related interpretive-bias and insomnia using the IAT. Specifically, sleep-associated monitoring, sleep preoccupation, sleep anticipatory anxiety and generalized anxiety. After excluding those reporting a co-occurring physiological sleep-disorder, those experiencing insomnia-symptoms demonstrated a sleep-related Interpretive-bias compared to normal-sleepers. When controlling for response time, time of testing, sleepiness, sleep-associated monitoring, sleep-preoccupation, sleep-anticipatory-anxiety and generalized anxiety, only monitoring on awakening predicted interpretive-bias. Multiple mediation modelling confirmed monitoring on awakening mediated the relationship between interpretive-bias and insomnia-symptoms.

Discussion

This review systematically identified studies that examined the presence of sleep-related attentional and interpretive-biases in individuals with poor-sleep, insomnia-symptoms, or insomnia disorder compared to normal-sleeping controls. The outcomes suggest that sleep-related cognitive biases of attention and interpretation are a key feature of insomnia. Specifically, 17 of 21 reviewed studies directly compared sleep-related attentional-bias between controls and poor-sleepers/insomnia patients, demonstrating small to large effects. Most (21/25) studies statistically support the presence of sleep-related attentional and interpretive-biases, yielding moderate effect sizes from meta-analytic data, with most estimates being positive.

Relationships between attention, interpretation & perception

Harvey's [12] cognitive model of insomnia suggests that selective attention increases the likelihood that people with insomnia will notice ambiguous sleep-related cues, subsequently interpreting them in line with the disorders symptom experience. Consequently, sleep-related interpretive-biases may accentuate pre-existing arousal and anxiety concerning sleep, cyclically perpetuating the sleep-disturbance. Likewise, the AIE pathway [6] proposes that selective attention precedes and contributes to sleep-intention and sleep-effort, culminating in reduced automaticity of normal-sleep. Here, selective attention is considered to propagate cognitive and somatic sleep-related arousal during the pre-sleep period and throughout the day. Indeed, heightened pre-sleep cognitive and somatic arousal has been associated with increased sleep-related attentional and interpretive-bias outcomes in poor-sleepers [32,47,48]. In individuals exhibiting insomnia-symptoms, interpretive-bias outcomes are associated with daytime-sleepiness, anxiety, sleep-preoccupation and sleep-related monitoring on awakening and throughout the day [47]. Interestingly, only monitoring for insomnia-consistent cues on awakening predicted increased interpretive-bias scores amongst those experiencing insomnia-symptoms [47]. Therefore, whilst sleep-related interpretive-biases are characteristic of the insomnia experience, the extent of bias appears to be mediated by pre-sleep worry and monitoring for cues that confirm poor-sleep on awakening [47,48]. Certainly, the combination of pre-sleep arousal and morning examination of internal bodily sensations and physical appearance may perpetuate negatively toned cognitive activity described in cognitive models of the disorder [6,12].

Self-reports of sleep-associated monitoring on awakening (but not throughout the day) mediate the relationship between negative interpretations of cutaneous body image and insomnia-symptoms [51]. Similarly, qualitative interviews amongst individuals with insomnia highlight monitoring of internal and external environment upon awakening as a means of assessing the extent of poor-sleep obtained [52]. Here, increased attentional-bias led to negative self-appraisal (i.e., interpretive-bias). Internally, the body was perceived as sore, heavy and unrefreshed, whereas externally, attention was focused on facial appearance (heavy eyes, poor complexion). Relatedly, promoting sleep-misperception upon awakening using false feedback about the sleep obtained served to alter the perception of daytime deficits in those with insomnia [53]. Specifically, on days following false feedback suggesting poor-sleep, the authors observed increased negatively toned cognitive activity, sleepiness, sleep-related attentional-bias, and use of safety behaviours compared to days when false positive feedback was received [54]. This was recently echoed where sham negative feedback about sleep was associated with greater reports of daytime dysfunction and fatigue relative to those receiving positive feedback [50]. However, no differences in attentional-bias emerged. Therefore, the period immediately following awakening appears crucial in attentional processing of sleep-related stimuli in those with insomnia, possibly facilitating disorder-consistent interpretation and subsequent (mis)perception of daytime impairments. Indeed, if attentional-bias on awakening was eliminated, this could theoretically: reduce the interpretation of ambiguous cues in a way that confirms poor-sleep, eliminating two key maintaining factors of the disorder; and circumvent the exacerbation of additional perpetuating factors highlighted in cognitive models [6,12] (i.e. sleep-related arousal, misperception of deficits, sleep-efforts).

Another vital question concerns the relative roles of psychological and physiological features of insomnia in predicting cognitive biases of information processing in insomnia [55]. Studies evidence no bias of attention towards sleep-related stimuli in DSPS [30,34] suggesting physiological sleep-disturbances fail to cause an attentional-bias. Indeed, normal-sleepers maintain a stable bias of attention towards sleep-related stimuli using the EST over 36 h of sustained wakefulness [55]. Together these findings indicate attentional-biases in insomnia predominantly occur due to the psychological processes outlined in cognitive models.

Cortical activity and cognitive bias

Observing brain reactivity in response to sleep-related stimuli may provide a timeline of cognitive-bias whilst providing insight into the roles of vigilance and disengagement, and threat versus craving [23,27,31,43,56]. Baglioni and colleagues [43] found that, compared to normal sleeping controls, individuals with insomnia show greater levels of amygdala reactivity during fMRI recordings in response to free viewing of sleep-related images. In people with insomnia, event-related potential (ERP) data showed evidence that

negatively valanced sleep-related words presented during an EST yielded higher amplitudes of P1 and N1 components in the occipital region, relative to sleep-positive and sleep-unrelated words [27]. This effect was not observed amongst normal-sleeping controls. Here, P1 and N1 represent early ERP components which reflect the automatic sensory process in response to external stimuli. More specifically, the observation of higher P1 and N1 amplitudes infers evidence of early cortical vigilance towards negative sleep-related words [27]. Interestingly, this study failed to evidence greater amplitudes of later ERP components (i.e., N2 or P3) which would be required to shift attentional allocation away from sleep-related words. This latter outcome falls in line with the many studies which suggest that difficulties in disengaging from sleep-related stimuli are a prominent feature of insomnia [6–22,22–28,28,29,29–35]. At present, interpretation of this data should be considered preliminary when accounting for the limited number of studies examining brain reactivity and attentional bias in insomnia, and the emergence of null outcomes. Indeed, Spiegelhalder and colleagues [23] failed to evidence differences between insomnia patients and controls in relation to attentional bias outcomes or cortical activity in response to the presentation of sleep-related words when using the EST and free-viewing tasks. Kim et al. [50] evidenced that the precentral, prefrontal, and posterior cingulate cortex areas in the brain of insomnia patients exhibited greater activation in response to the free viewing of sleep-related images but not neutral images when compared with normal sleepers. The precentral cortex of insomnia patients is known to elicit increased connectivity to the amygdala and sensory cortices [56] and might be related to hyperarousal of the psychomotor system in the context of sleep-related anxiety in insomnia [57]. In relation to the current context, the neural processing of sleep-related stimuli may serve to accentuate the hyperarousal of precentral cortical activity amongst those with insomnia. The most novel outcome [57] pertains to the normalised brain reactivity following the successful completion of Cognitive Behavioural Therapy for Insomnia (CBTi). As per the AIE model [6], which proposes that attentional bias precedes sleep intent and behavioural sleep-efforts, these outcomes further highlight the potential therapeutic role of targeting sleep-related cognitive biases, possibly as an adjunct to CBTi [6,12].

Methodological influence

Task & stimuli

The variation in sleep-related cognitive bias outcomes may partly stem from methodological differences pertaining to the task and stimuli used. Indeed, when examining group differences (insomnia/poor-sleeper vs. control) in attentional-bias, eye-tracking paradigms involving free-viewing consistently yielded moderate to large effect sizes, specifically when using pictorial stimuli [35,36] relative to words [37]. With reaction time as the critical measure of attentional-bias, the pictorial flicker task reliably yielded large between group effects [28,29].

EST reaction time data fails to capture attentional-bias relative to the interference index. Therefore, we chose to calculate and include Interference scores where necessary [i.e.,21–22]. Specifically, five [21–25] of six [31] studies evidenced group differences (insomnia/poor-sleeper vs. control) in Stroop interference when processing sleep-related information with moderate to large effects. Apart from one study [39], the dot-probe task appears to reliably evidence group differences in attentional-bias for sleep-related words and images with moderate to large effect sizes [28–32]. Three studies calculated vigilance and disengagement indices [29-29,32], whereas the remaining studies calculated task interference as the critical measure of attentional-bias [30,31]. Here, the presence of a sleep-related attentional-bias appears largely attributable to difficulties in orienting attention towards, and disengaging attentional resources from, the spatial location of insomnia salient stimuli [28,29,32]. Difficulties in disengaging attention from sleep-related stimuli were also observed using the Posner task [38].

As previously mentioned, most of the research to date confirms the presence of a sleep-related interpretive-bias amongst poor-sleepers and individuals when compared to normal-sleeping controls. Here, studies opting to analyse responses to forced choice questions yielded moderate to large effects [45–48] relative to reaction time tasks which yielded mostly small to moderate effects [7,50].

Control variables

Given the prevalence of co-occurring symptoms of anxiety and depression in people experiencing poor-sleep or insomnia [3], most sleep-related cognitive bias studies have controlled for psychiatric symptoms in pre-screening or statistical analysis. This is to ensure that the presence of any emerging cognitive bias is driven by the experience of insomnia, rather than comorbid factors. In the reviewed studies, symptoms of anxiety and/or depression were either: statistically controlled for [28,40,44,45,48,50]; assessed with no need to control for symptoms [43,44]; assessed but not controlled for [30,35,38,49]; or controlled for using anxious and sleep-related stimuli [7]. Many studies excluded participants based on the presence of psychiatric symptoms at the pre-screening stage [23,29,31,33,34]. Other studies failed to examine symptoms of anxiety and depression [21,25,26,32,46], whereas few controlled for other sleep-disorder symptoms or sleep-related variables (e.g., chronotype, sleepiness, sleep-related arousal) which may possibly influence perceptual judgments when observing sleep-related stimuli [22,23,30,31,34,47,48].

Sample, population & design

Data from $N = 1499$ participants were included in this review, $N = 922$ from attentional-bias studies (mean sample-size = 60.10), and $N = 277$ from interpretive-bias studies (mean sample-size = 96.75). Overall, the reviewed studies involved small sample sizes ranging from 31 to 192 participants. Moreover, sampling was disproportionately limited to the United Kingdom ($N = 13$) and Germany ($N = 8$). Few studies were conducted in the rest of Europe ($N = 2$), the United States ($N = 2$), Australia ($N = 1$) or China ($N = 1$). All studies collected cross-sectional data. Moreover, a disproportionate number of Caucasian female participants was observed, and several of the included studies restricted their sample students [7,27,30,38,41,46,49,50].

Most sleep-related attentional-bias studies (15/21) sampled individuals meeting diagnostic criterion for insomnia. Nine sampled insomnia patients, whereas the remaining employed diagnostic screening to identify insomnia-disorder. Two of 8 interpretive-bias studies sampled individuals with insomnia-disorder [48,50], whilst the remaining deployed questionnaires assessing insomnia-symptoms.

Suggestions for future work

Moving forward, we offer suggestions for future researchers to consider which may improve and expand on the sleep-related cognitive bias literature whilst providing a greater understanding of cognitive models of insomnia. The priority however should involve addressing the limitations discussed above (i.e., sample size, cross-sectional design).

Mediating factors

As discussed, the exploration of potential mediational factors fundamental to the sleep-related cognitive bias and insomnia relationship has only recently begun in the context of interpretive bias outcomes [47–49]. In a recent theoretical perspective, we propose candidate factors that may play a crucial role in addressing moderating questions such as "when," "for whom" and "under which" conditions are sleep-related attentional biases evident in individuals characterised by insomnia [58]. More specifically, the relative role(s) of: the 5HTTLPR polymorphism and brain reactivity; valence of mood state; sleep-related worry; and misperception of sleep and daytime impairment have been suggested [58].

Methodological approach

Moving forward from reaction time assessments of attentional bias, which can be considered an indirect measure of attention, several studies have used eye-tracking paradigms to examine selective attention in insomnia [35–37]. Here, visual attention can be continuously recorded throughout stimuli presentation to determine where individuals with insomnia direct and fixate their gaze, providing an objective and direct assessment of attention [59–61]. Likewise, recent advances using virtual reality environments have significantly improved the proximity and salience of disorder congruent stimuli when assessing attentional bias in individuals experiencing anxiety [62,63], depression [64,65] and body image disturbance [66]. Certainly, virtual reality paradigms could improve the ecological assessment of cognitive bias in insomnia. For example, expanding on images of the bedroom, participants may be exposed to an immersive bedroom environment.

Future work should focus on the integration of sleep-related attentional and interpretive biases measures [11] to identify the relative contribution of each cognitive process to insomnia. Future reaction time tasks may be paired with eye-tracking, virtual reality or EEG paradigms with a focus on capturing the relationship between initial attention allocation to sleep-related cues and the subsequent influence on perceptual judgments (i.e., interpretation bias). This approach would also allow a greater understanding of how sleep-related cognitive biases are characterised in the context of vigilance and disengagement.

Finally, sleep-related cognitive bias studies remain limited to cross sectional data. Moving forward, longitudinal approaches should be deployed to confirm the temporal stability of sleep-related cognitive biases. Here, short, and long-term protocols would involve the same task being completed across several time points. With that in mind, the time of day is known to influence the outcomes of experimental emotion perception tasks amongst those with insomnia [67]. Therefore, the periodic (e.g., morning, afternoon, evening) examination of sleep-related cognitive biases over the course of several days would account for potential outcome variation across the day. In contrast, studies involving weekly testing over a wider timespan would confirm the longitudinal stability of sleep-related cognitive biases [68]. In the context of insomnia, this line of enquiry seems particularly pertinent when considering mixed outcomes concerning the test-retest reliability of attentional bias tasks in other psychiatric populations including anxiety and depression [69–72].

Attentional bias modification

Deploying attentional bias modification (ABM) paradigms immediately prior to nocturnal sleep-onset may be used to reduce the extent of sleep-related attentional bias in insomnia, and therefore, lead to an associated reduction in symptom severity [73,74]. Here, attentional avoidance of negative sleep-related information is facilitated using a modified dot-probe task where the target location always follows the placement of neutral (i.e., location opposite sleep-related) stimuli. Following repeated exposure over consecutive days, this paradigm may 'train' an individual's attention away from negative information related to their specific condition and towards more neutral information [75]. The immediate effects of ABM appear to be most prominent when implemented just before the event which is perceived as threatening to the population [76]. In the context of sleep, poor sleepers completing ABM immediately before attempting sleep reported improved sleep quality, reduced pre-sleep arousal, and reduced sleep onset latency relative to alternative nights where a control task was completed [73,74]. Expanding on this research, Lancee et al. [77] evidenced no therapeutic effect of ABM amongst those meeting diagnostic criteria for insomnia. However, this study delivered ABM in the evening between 7 and 11 p.m., rather than the individuals immediate period before sleep, where biased attention may be more prominent [73]. Whilst this work appears promising, further studies are required to determine the efficacy of ABM amongst individuals with insomnia.

Conclusions

Theoretical models highlight the crucial role of sleep-related attentional and interpretive-biases in the development and maintenance of insomnia [6,12]. The current meta-analysis and systematic review advocate disorder congruent attentional and interpretive-biases as a key feature of the disorder. Indeed, most analysed studies lend statistical support for this notion, with comparable effects for both sleep-related attentional and interpretive-biases. Our findings highlight methodological factors related to task design, sample and stimuli, which may influence outcome variation. Given slight heterogeneity among studies and absence of longitudinal data, we cannot infer causal influence on the development and maintenance of insomnia. Therefore, longitudinal research should clarify the presence of cognitive-biases in insomnia using experimental designs, whilst examining potential mediating factors.

Practice points

1 In support of key cognitive models of insomnia, most of the reviewed studies evidence sleep-related attentional and interpretive biases based on cross-sectional data.
2 Given the theorised developmental and maintaining role of sleep-related cognitive biases in relation to insomnia, attentional bias modification paradigms may serve to reduce the symptom experience of such biases.

Research agenda

1 The absence of longitudinal data limits determination of directional causality and interaction between attention and interpretation. Future work should prioritise studies of a prospective design.
2 The role of possible mediating and moderating factors underlying sleep-related cognitive biases should be further explored.
3 The role of cortical activity in response to sleep-related stimuli in insomnia may serve to clarify key questions pertaining to the relative roles of vigilance vs. disengagement and threat vs. craving.
4 Finally, larger, and more representative samples are required.

Declaration of competing interest

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Data Availability statement

Data will be made available on reasonable request.

Acknowledgments

n/a.

Appendix ASupplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.smrv.2022.101713.

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