Sleep-related attentional bias in poor versus good sleepers is independent of affective valence

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SUMMARY

Contradictory evidence exists relating to the presence of an attention bias to sleep-related stimuli in poor sleepers/insomnia using the emotional Stroop task (EST). These inconsistencies may be due to methodological issues related to the affective valence of the sleep-related stimuli. Thus, individuals may attend differentially to sleep-related stimuli not because of their 'sleep' properties, but their negativity. The current study addresses this by controlling the affective valence of sleep-related words. A total of 107 participants [mean age = 33.22 years, standard deviation (SD) = 12.31 years; 61.7% female] were recruited during an evening event at the Newcastle Science Festival. Participants completed the Pittsburgh Sleep Quality Index (PSQI) and a computerized EST containing 20 non-affective sleep-related, 20 neutral and 20 negatively valenced threat words. Good and poor sleepers were categorized using the PSQI. There were no significant differences between groups on response latency to sleep-related words ($t_{(105)} = -0.30$, $P = 0.76$). However, the interaction between good versus poor sleepers and word-type on response latency was significant ($F_{(2,210)} = 3.06$, $P < 0.05$). Poor sleepers took longer to respond to sleep-related words (mean = 723.35, SD = 172.55) compared to threat words (mean = 694.63, SD = 162.17) than good sleepers (mean = 713.20, SD = 166.32; and mean = 716.65, SD = 181.14). The results demonstrate the presence of an attention bias towards sleep-related stimuli compared to threat stimuli in poor sleepers. Accordingly, poor sleepers may be consumed by stimuli relevant to their specific difficulties, as well as being more highly attuned to negative cues that signal anxious states. Thus, the present research suggests that there are two opposing forces at play: one which facilitates performance (non-specific threats) and one which hinders performance (personally relevant threats).

INTRODUCTION

Cognitive models of insomnia propose that sleep disturbance is, in part, maintained by selective attention to sleep-related threat cues (Espie *et al.*, 2006; Harvey, 2002). Accordingly, individuals with insomnia may become preoccupied with sleep to the extent that they monitor their internal (i.e. bodily sensations) and external environment selectively for sleep-related threats. Consequently, sleep-related stimuli become the focus of attention, and attempts to control the automaticity of sleep perpetuate the insomnia. The premise of these theories stems from work in the psychopathology literature which maintains that information processing in anxious individuals is biased towards encoding threatening stimuli (Dalgleish and Watts, 1990), and this focused attention may play a causal role in the development of anxiety (Mathews and MacLeod, 1994). In different contexts, such selective attentional processes act to both facilitate the detection of, and impair responses to, emotionally salient stimuli (Clark, 1999; Dalgleish and Watts, 1990; Williams *et al.*, 1996).

One method for examining experimentally the extent of selective attentional processes is the emotional Stroop task (EST) (Williams *et al.*, 1996). In the EST, neutral words and emotionally salient words are presented on screen in one of four colours. Participants are required to press a correspondingly coloured response key as quickly as possible. Longer response latencies to emotionally salient words are considered to represent an index of Stroop interference—that is, the content of the word presented consumes attentional resources such that performance is impaired. A substantial body of research has focused on attention bias in many aspects of psychopathology (for a review, see Williams *et al.*, 1996), and 11 studies to date have examined attentional processing in sleep with a specific focus on insomnia (seven of which used the EST).

Lundh *et al.* (1997) were the first to investigate the presence of a sleep-related attentional bias using the EST in patients with persistent insomnia compared to controls. While there was evidence of an interference effect to sleep-related words compared to physical threat words and control words, the effect was also present in normal sleepers. These results suggest that sleep-related stimuli may be equally as salient for both groups. Conversely, Taylor *et al.* (2003) investigated the role of attention bias using the EST in the development of persistent insomnia. Comparing attentional bias in cancer patients with acute or persistent insomnia, the authors found Stroop interference for both groups to cancer-related words, but only the persistent insomnia group to sleep-related words. These results suggest that sleep-related attention bias may be related to the maintenance, rather than onset, of insomnia. That said, Ellis *et al.* (in press) recently found an attention bias, using the EST alongside a mood induction paradigm, in children of parents with insomnia, suggesting it as a marker of an intergenerational vulnerability.

Using different paradigms, other studies provide evidence of a sleep-related attention bias in poor sleepers using the Flicker task (Jones *et al.*, 2005); in primary insomnia using the visual dot-probe (VDP) task (Jansson-Frömark *et al.*, 2012; MacMahon *et al.*, 2006); and in primary insomnia and delayed sleep phase syndrome (DSPS) using the change blindness paradigm (Marchetti *et al.*, 2006). The latter finding of an attention bias in DSPS as well as insomnia suggests that the salience of the general concept of sleep may be driving the attention bias rather than being driven by psychological concern over threat-related cues (which is uncharacteristic of DSPS). Spiegelhalder *et al.* (2008) tested the hypothesis that frequency of concept usage (that is, familiarity with, and usage of, the concept of 'sleep', which is considered to be greater in individuals with a sleep disorder as well as sleep researchers) contributes to attention bias by investigating its presence in patients with insomnia compared to sleep experts and controls using the EST and a mixed-modality task. Sleep-related attention bias using the EST was greater in the insomnia patients compared to sleep experts, suggesting that frequency of concept usage does not account for attention bias. However, there were no significant differences in attention bias between the insomnia patients and controls, contradicting previous work as well as later work by the same authors (Spiegelhalder *et al.*, 2010). Spiegelhalder *et al.* (2010) also examined the impact of sleep-related attention bias, using the EST and VDP on polysomnographically defined sleep in primary insomnia and controls. While EST attention bias scores were not associated with polysomnographic variables, VDP attention bias scores were associated with improvements in measures of sleep continuity the night following the task, suggesting that attention bias may represent an index of sleep craving.

Other studies have aimed to determine whether attention bias is influenced by sleepiness or sleeplessness. Sagaspe *et al.* (2006) assessed the degree of Stroop interference to sleep-related words in normal sleepers following 36 h of sleep deprivation. They hypothesized that the anxious state induced by sleep deprivation would heighten attention towards threatening stimuli. However, there was no evidence that sleepiness alone can account for attention bias. Later, Spiegelhalder *et al.* (2009) assessed associations between sleeplessness, sleepiness and attention bias (using both a mixed-modality task and the EST) in a non-clinical sample. Both sleepiness and sleeplessness demonstrated linear relationships with attention bias using the EST, such that increases in poor sleep quality and sleepiness were associated with increased attention bias scores. Given that the sample was below the clinical threshold for insomnia, this study suggests that attention bias is present in subclinical sleep disturbance. This is in line with cognitive models of insomnia, which suggest that attention bias may play a role in the development, as well as maintenance, of more persistent problems (Espie *et al.*, 2006; Harvey, 2002).

Despite a growing interest in the cognitive processes underlying sleep disturbance and insomnia, what is clear from the above review is the inconsistency in the literature surrounding sleep-related attention bias using the EST. While some studies find evidence of an attention bias across the developmental course of insomnia, others find no differences compared to good sleepers. We propose here that these inconsistencies may be accounted for by the affective properties of the stimuli used. Although previous studies have attempted to create sleep-related word lists that emulate sleep or the sleeping environment, some of the words used have negative connotations (e.g. tired, fatigue, lethargy, exhausted, nightmare, dark) (although we note that the word lists used in all previous studies contained a mixture of affectively neutral as well as negatively toned sleep-related words). It is possible that such words could be interpreted as equally threatening by both individuals with and without sleep disturbance. The non-specific threatening nature of these words may blur the distinctions that we would expect to see on Stroop interference for sleep-related words between good and poor sleepers. Furthermore, research in the psychopathology literature has compared the Stroop interference effect using emotionally salient words specific to the psychopathology as well as unrelated threatening words to disentangle whether interference is simply a product of general, rather than specific, threat (Williams *et al.*, 1996). For example, Mathews and MacLeod (1985) found that anxious patients whose concerns were predominantly about social issues showed Stroop interference for social-threat words but not physical-threat words. While there has been some attempt to compare general versus specific threat in some of the EST research relevant to sleep (Lundh *et al*., 1997; Sagaspe *et al*., 2006; Taylor *et al.*, 2003), results are inconsistent, and none of this previous research has controlled the affective valence of the sleep-related words. Insomnia and anxiety are highly comorbid, and indeed anxiety often precedes insomnia (Johnson *et al*., 2006), which makes likely the explanation that attention bias is affectively orientated.

Accordingly, the present study aimed to determine whether individuals experiencing sleep disturbance (compared to good sleepers) attend specifically to the sleep-related properties of the words presented or whether they have a more general tendency to attend to threatening stimuli by using affectively neutral, but psychologically salient sleep-related, words compared to neutral and non-specific threat words. For two reasons, a sample of poor sleepers was used in this study rather than a sample of individuals with primary insomnia. First, the symptoms of and processes underlying insomnia can be considered to exist along a continuum, varying between subclinical and clinical populations in terms of severity and intensity, albeit being the same processes in both (Morin *et al.*, 2009; Ree *et al.*, 2006). Secondly, while some research points to the possibility that sleep-related attentional bias relates to insomnia maintenance (Lundh *et al.*, 1997; Taylor *et al.*, 2003), studies which have observed the sleep-related attentional bias in subclinical samples of poor sleepers suggests that it may be a precursor to insomnia, rather than an epiphenomenon (e.g. Ellis *et al.*, in press). Focusing on a sample of poor sleepers will enable us to identify the presence of attentional bias at the subclinical stage.

In addition, the majority of work on the EST considers only correct responses. It is likely that faster responses are more prone to errors, given that less time attending to a stimulus may reduce precision and accuracy. Thus, if an individual is attempting to avoid a stimulus (such as one of a threatening nature), and thus makes a fast yet incorrect response, omitting these data on the basis of its inaccuracy means that we are masking our primary variable of interest (i.e. speed). Furthermore, it is possible that individuals with an attention bias would make fewer errors to salient stimuli given the increased response latency on relevant trials. Thus, the percentage of correct responses may be used as an index of attentional resources expended. Therefore, a secondary aim of the present study was to assess attention bias after excluding errors as well as using all trials including errors, and also to compare the percentage of correct responses across stimuli between good and poor sleepers.

METHODS

Participants

A total of 155 volunteers were recruited for the study during an evening event at the Centre for Life, Newcastle, UK as part of the Newcastle Science Festival in 2012. One hundred and thirty-four participants provided complete data relevant to the current analyses; however, 27 participants indicated that they had a history of either a medical or psychological disorder, and so were excluded from analysis. While previous studies within the attention bias literature have not excluded participants on this basis, we decided to do so here so that we could assess the extent to which sleep disturbances alone drive attention bias, independent of concomitant complaints. Based on previous recommendations (McNally *et al*., 1994; Taylor *et al*., 2003), response latency data were inspected for outliers <300 milliseconds (msec) and >2000 msec; however, no trials met this criteria and so no cases were excluded on this basis. In total, 107 participants were selected for analysis [mean age = 33.22 years, standard deviation (SD) = 12.31 years, range 18–71; 61.7% female; 94.4% white]. The sample was well educated, with 97.2% educated to A-level or equivalent and above. Ethical approval was granted by the Northumbria University, School of Life Sciences ethics committee, and written informed consent was provided by all participants.

Materials

Sleep quality was assessed using the Pittsburgh Sleep Quality Index (PSQI: Buysse *et al.*, 1989)—one of the most widely used measures to assess sleep quality in the past month. The PSQI contains 18 items tapping into several different aspects of sleep, including subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, medications to aid sleep and daytime dysfunction. The PSQI global score has a range of 0–21, with scores >5 considered to indicate significant disturbances from sleep (Backhaus *et al*., 2002). This cutoff score is used here to differentiate good from poor sleepers.

The computerized emotional Stroop task was used to investigate attention bias. Written words were randomly presented individually in the centre of the 15.5-inch computer screen in one of the following colours: red, blue, green, yellow. Coloured keys on the computer keyboard were used to record responses. Participants were instructed to place their index and middle fingers over the keys and to press the correctly coloured key on the computer keyboard corresponding to the colour of the word on screen as quickly as possible. A fixation cross was presented for 500 ms prior to the word stimuli and between each word. The words were displayed on screen until a response was made. Participants were first given a practice trial of 20 additional neutral words, followed by 60 experimental trials containing 60 words. Word lists contained 20 sleep-related, 20 neutral and 20 non-specific threat words (see Table 1). The sleep-related words were chosen specifically to be void of any affective connotations. Non-specific threat words were selected from the affective lexicon (Clore *et al*., 1987). All words on the experimental trials were matched in terms of word length and number of syllables.

Table 1 Words used in the emotional Stroop task

Sleep-related words	*Neutral words*	*Non-specific threat words*
Sleep	Plate	Cruel
Dream	Chord	Dread
Bed	Cat	Ill
Night	Crown	Shame
Snooze	Change	Grieve
Pillow	Number	Scared
Duvet	Towel	Upset
Blanket	Between	Useless
Mattress	Keyboard	Helpless
Quilt	Grasp	Shock
Pyjamas	Through	Jealousy
Bedtime	Camping	Hateful
Slumber	Jumping	Worried
Nap	Now	Bad
Doze	Once	Glum
Nightgown	Something	Disgraced
Shuteye	Fishing	Hostile
Alarm Clock	Housework	Vulnerable
Awake	Table	Panic
Asleep	Travel	Rotten

Procedure

The computerized emotional Stroop task was carried out in a well-lit, quiet area of the exhibit hall during the Newcastle Science Festival, between 19:00 and 22:00 hours. Before commencing the emotional Stroop task, participants were required to give their informed consent and answer a questionnaire booklet containing a demographic questionnaire, including one question asking whether the participant had a history of a medical or psychological disorder, and the PSQI. Participants were then given standardized verbal instructions on the emotional Stroop by trained researchers as well as on-screen written instructions. Once participants indicated that they understood the instructions they commenced the 20 practice trials to familiarize themselves with the task, followed by the experimental trials. The researcher remained in the area until completion of the task, after which participants were debriefed on the aims and purposes of the research.

Analyses

A 2 (sleep quality group) $\times$ 3 (word-type) repeated-measures between-group design was employed. The primary outcome measure from the emotional Stroop task was the absolute response latency following presentation of individual words. Response latencies were measured in msec. Between-group differences in response latencies to the different word-types were analysed using repeated-measures analysis of variance (ANOVA) to assess the main effects of group and word-type as well as the group $\times$ word-type interaction. Analyses were run first on trials excluding errors, and secondly incorporating all trials (including errors). Finally, the same analyses were performed using the percentage of correct responses as the outcome measure. For all analyses, significance was considered at the $P < 0.05$ level (two-tailed).

RESULTS

The total sample had a mean PSQI score of 5.59 (SD = 2.97), an overall mean response latency of 713.99 (SD = 169.82) and 3.10% of emotional Stroop trials were errors. There were no significant differences between males and females on PSQI score ($t_{(105)} = 0.53$, $P = 0.60$) or overall response latency ($t_{(104.90)} = -1.63$, $P = 0.11$), but there were significant differences in the percentage of errors ($t_{(48.45)} = -2.90$, $P < 0.05$). Males made significantly more errors (4.67%) than females (2.12%). There were no significant between-group (good versus poor sleepers) differences in the distribution of males and females ($\chi^2_{(1)} = 1.40$, $P = 0.31$), age ($t_{(101.61)} = -1.46$, $P = 0.15$) or education ($t_{(105)} = -1.42$, $P = 0.16$).

When excluding errors on the emotional Stroop task, there were no significant main effects of sleep quality group or word-type on response latency ($F_{(1, 105)} = 0.02$, $P = 0.88$; $F_{(2, 210)} = 1.90$, $P = 0.15$, respectively) (see Table 2 for means and standard deviations). However, the interaction between word-type and sleep quality was significant ($F_{(2, 210)} = 3.06$, $P < 0.05$). Pairwise comparisons revealed that response latencies to sleep-related words were significantly longer than non-specific threat words for poor sleepers, but not good sleepers ($F_{(1, 105)} = 5.99$, $P < 0.05$)

Table 2 Sample characteristics and response latencies to emotional Stroop task by word-type (means $\pm$ standard deviation)

	Total (n = 107)	*Good sleepers (n = 65)*	*Poor sleepers (n = 42)*
PSQI	5.59 ± 2.97	3.66 ± 1.14†,*	8.57 ± 2.42†,*
Mean RL overall	712.95 ± 169.35	714.79 ± 173.00	710.10 ± 165.57
Mean RL Sleep-related words	717.19 ± 168.05	713.20 ± 166.32	723.35 ± 172.55‡,*
Mean RL Neutral words	713.79 ± 179.22	714.98 ± 185.01	711.93 ± 172.07
Mean RL Non-specific Threat words	708.00 ± 173.50	716.65 ± 181.14	694.63 ± 162.17‡,*

PSQI, Pittsburgh Sleep Quality Index; RL, response latency (measured in msec) for trials excluding errors.
*$P < 0.05$.
†Comparison between good versus poor sleepers.
‡comparison between sleep-related versus non-specific threat words.

(see Fig. 1). The difference between sleep-related words and neutral words was not significantly different for good or poor sleepers ($F_{(1,\ 105)} = 0.99$, $P = 0.32$).

When including all trials (as well as those containing errors), a similar pattern of results emerged. There were no significant main effects of sleep quality group or word-type on response latency ($F_{(1,\ 105)} = 0.03$, $P = 0.87$; $F_{(2,\ 210)} = 1.90$, $P = 0.15$, respectively), and the overall interaction between word-type and sleep quality on response latency was significant ($F_{(2,\ 208)} = 3.50$, $P < 0.05$). As before, pairwise comparisons revealed that that response latencies to sleep-related words were significantly longer than non-specific threat words for poor sleepers compared to good sleepers ($F_{(1,\ 105)} = 6.45$, $P < 0.05$).

There were no main effects of sleep quality group or word-type on percentage of correct responses ($F_{(1,\ 105)} = 0.00$, $P = 0.95$; $F_{(2,\ 210)} = 0.12$, $P = 0.89$, respectively). The interaction between sleep quality group and word-type on percentage of correct responses was also non-significant ($F_{(2,\ 210)} = 1.39$, $P = 0.25$).

DISCUSSION

The principle aim of this study was to determine whether a sleep-related attention bias exists in poor sleepers after controlling for the affective valence of the stimuli. There are three noteworthy findings from the present study: (i) response latencies to sleep-related stimuli were similar between good and poor sleepers; (ii) poor sleepers compared to good sleepers responded significantly slower to the affectively neutral sleep-related words compared to non-specific threat words; and (iii) there were no significant differences between groups on percentage of correct responses on the Stroop task.

The finding that good and poor sleepers responded similarly to the sleep-related words suggests that sleep-related stimuli are equally as important for both groups. This finding is in line with that of Lundh *et al.* (1997), who found no group difference between primary insomnia patients and controls on sleep-related Stroop interference. In the present sample this is perhaps not surprising, given that the study was carried out during the evening, and so the topic of sleep may have been particularly salient for all participants—the response representing craving for sleep, presumably via the homeostatic drive. However, where Lundh *et al.* observed an overall attention bias towards sleep-related stimuli compared to neutral words in all participants, this effect was not evident here. In the present study, when comparing sleep-related and neutral stimuli, there was no evidence of a sleep-related attention bias generally or between good and poor sleepers. This concurs with the work of Spiegelhalder *et al.* (2008), who found no group differences between primary insomnia patients and controls on sleep-related and neutral words. Nevertheless, this result contradicts the majority of the sleep-related attention bias literature, which has found significant group differences on sleep-related Stroop interference compared to neutral words.

We hypothesized initially that the attention bias to sleep-related compared to neutral words found in previous research may be driven by an underlying attention bias towards threatening stimuli generally, rather than related specifically to sleep. Because some of the sleep-related words used in previous studies are inherently negative in nature, we speculated that poor sleepers may simply be attending to the threatening nature of the stimuli rather than the sleep-related content. Because the sleep-related words used in the present study were void of any affective connotations, and because we had a comparison between neutral and threatening words, we were able to tease apart these effects. However, the finding that response latencies were significantly faster for the non-specific threat than sleep-related words (with no difference in comparison to neutral words) was unexpected. This suggests that performance is facilitated by non-specific threatening stimuli, yet hindered by personally relevant stimuli. As such, it appears that the sleep-related attentional bias is driven by the salience of sleep rather than via a more general anxiety-type response to threat. The present findings may help to explain previous studies that have found no sleep-related attention bias. If poor sleepers attend differentially to the sleep-related content (hindered performance) and the threatening nature (facilitated performance) of the affectively valenced sleep-related stimuli, we would expect these effects to confound one another. As a result, these effects would counteract the attention bias to affectively valenced sleep-related words.

A possible explanation for our unexpected finding is that exposure to non-specific, threatening stimuli activates an anxiety schema which provokes a vigilance–avoidance response, so that the threatening stimuli are actively avoided (resulting in a shorter response latency). Because anxiety states are not conducive to sleep, it is possible that poor sleepers act to avoid anxiety states that may be predictive of a poor night of sleep. However, when presented with

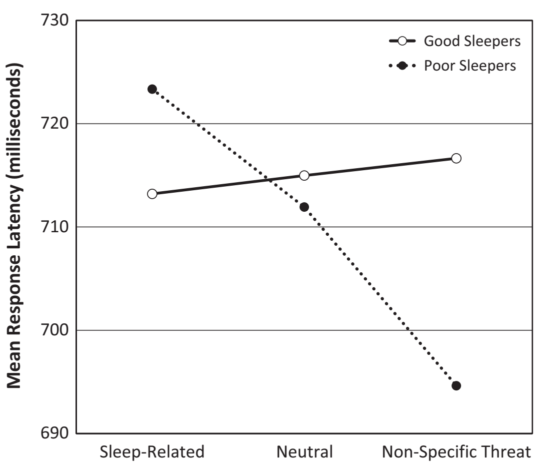

Figure 1. Interaction between word-type and sleep quality on mean response latency excluding trials with errors.

personally relevant sleep-related stimuli, attentional resources are consumed to the extent that performance is hindered. Support for the vigilance–avoidance response to anxiety-provoking stimuli can be observed in the psychopathology literature, where it has been suggested that highly anxious individuals enter a vigilant mode easily when presented with threat cues (Mathews, 1990). As prolonged exposure to a vigilant mode may exacerbate the anxiety experienced (Mathews, 1990), it is possible that non-specific threatening stimuli are avoided rather than increasingly attended to, thus accounting for the faster response latency. Thus, if it is the case that poor sleepers face two opposing forces, one which facilitates performance (non-specific threats) and one which hinders performance (personally relevant threats), previous research using sleep-related stimuli (personally relevant) which are negatively affective (non-specific) may be intrinsically confounded. This could account for the inconsistencies within the literature. Accordingly, the present study suggests that poor sleepers may be more highly attuned to negative cues that may signal an anxious state, as well as being consumed by stimuli relevant to their specific difficulties.

However, within the anxiety literature cognitive avoidance has been suggested to result in longer response latencies, due to the increased cognitive processing capacity involved in actively avoiding a stimulus (De Ruiter and Brosschot, 1994). Our contradictory finding of shorter response latencies to threatening stimuli suggests that perhaps different mechanisms are involved in poor sleepers. Our findings seem to be consistent with the idea that poor sleepers allocate cognitive resources to the object of their craving (sleep) and, therefore, lack the cognitive resources to also attend overly to non-specific threats. Therefore, they have a facilitated performance in responding to non-specific threat cues. This explanation challenges the view from the anxiety literature that cognitive avoidance produces an interference effect, which highlights the necessity for research aimed specifically at differentiating the processes of resource allocation and cognitive avoidance in poor sleep and anxiety.

While individuals with a history of medical or psychological disorder (i.e. anxiety) were excluded from our analyses, we consider anxiety-type traits to exist on a continuum, rather than just at the clinical poles presenting as a disorder. Therefore, it is possible that such anxiety-type processes may have accounted for the faster response times observed to the threatening stimuli. Thus, even though the observed effect is not driven by an anxiety disorder *per se*, the differential effects towards sleep-related and threatening stimuli appear to be driven by independent sleep-specific and anxiety-type traits, respectively. Further research focusing specifically on sleep disturbances comorbid with anxiety disorder is necessary in order to determine whether the same mechanisms underlie attention bias at the clinical pole of anxiety.

A secondary aim of the present study was to determine whether or not a different pattern of results would emerge if analyses were run using all trials compared to trials excluding errors (as is typical in research of this kind). As it is plausible that faster responses are more likely to produce errors due to a lack of precision and accuracy, omitting erroneous trials means that we are potentially omitting the fastest responses, and hence a great deal of meaningful data. Accordingly, previous research which has suggested that attempts to avoid threatening stimuli may produce longer response latencies (given that this process may require increased processing capacity) has not considered erroneous (and potentially faster) responses, which may be more intuitively indicative of avoidance. While we found no differences in our pattern of results when including and excluding errors, or between the proportion of correct responses between good and poor sleepers, this is due probably to the small proportion of errors made (~3%). We suggest that future research takes this into consideration when interpreting response latencies in terms of attention bias, resource allocation and cognitive avoidance.

Despite our novel findings, there are several limitations of this study that warrant consideration. Firstly, we used the PSQI to differentiate our good and poor sleepers rather than comparing patients with primary insomnia to controls. However, understanding variability at the subclinical poles has the potential to inform nosology. This is especially important, as it has been suggested that attention bias may be involved in the development of insomnia (Espie *et al.*, 2006). Accordingly, these findings may further our understanding of the cognitive processes underlying insomnia. Secondly, while we excluded participants indicating that they had a history of medical or psychological disorder, we did not control specifically for anxiety in our analyses. This is important to consider, as it is likely that comorbid anxiety disorders would affect attention bias in individuals with poor sleep. Similarly, we did not take into account current mood state when measuring attention bias. This is important to consider, as information processing has been shown to be affected by mood (Mogg *et al.*, 1994). While the inclusion of measures to assess specifically anxiety and depression and current mood state would have enabled us to control for their effects on attention bias, the nature of the method of data collection (i.e. at a public engagement event) limited the number of questionnaires included in the study in order to reduce participant burden. Thirdly, participants completed the PSQI prior to engaging in the emotional Stroop task, and so there is a possibility of a sleep-related priming effect. However, if this were the case we would expect that response latencies to sleep-related words to have been faster compared to the other stimuli if priming had indeed occurred. Accordingly, the present results may be somewhat conservative if a priming effect was present. Finally, there have been criticisms on the use of the Stroop task as a measure of selective attention. One argument is that the emotional Stroop may be considered to be a measure of heightened arousal, which impairs information processing when faced with salient stimuli, rather than a measure of increased vigilance towards such stimuli (Espie *et al.*, 2006). This distinction is important as, according to Harvey's (2002) cognitive model, both increased arousal and vigilance are features of insomnia, and it is thus important to determine the mechanism through which the effect occurs. Using the dot-probe task, a recent study has demonstrated that attention bias in insomnia is due to an inability to disengage from sleep-related stimuli, rather than increased vigilance towards such stimuli (Jansson-Frömark *et al*., 2012). Replicating this finding through alternative mediums, such as the EST, and examining differential effects towards threatening and neutral stimuli, will enable us to draw firmer conclusions regarding the processes (i.e. arousal, vigilance, avoidance, resource allocation and disengagement) underlying attention bias in different populations. Furthermore, the use of words as stimuli in the emotional Stroop task has been criticized on the grounds that the affective intensity of threatening words may not vary sufficiently from neutral words to elicit a differential threat response (Yiend and Mathews, 2001). However, the fact that a significant difference between word-type (sleep-related versus threat) was found in poor sleepers (compared to good sleepers) in the present study suggests that the stimuli used differentiated adequately between these two affective states.

Despite these limitations, this is the first study of attention bias in relation to sleep to tease apart the effects of sleep-related versus affective threat using the emotional Stroop. While there were no differences between good and poor sleepers in response latency to sleep-related words, poor sleepers showed significant differentiation between sleep-related words and non-specific threat words. This finding suggests that poor sleepers may have two opposing forces at play: one representing an attention bias towards sleep-related stimuli, and another representing heightened vigilance or avoidance for anxiety provoking stimuli. This finding adds to our understanding of mechanisms of information processing in the development of insomnia.

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DISCLOSURE STATEMENT

The authors declare no conflicts of interests in relation to this paper.

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