Attention to beds in natural scenes by observers with insomnia symptoms

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Highlights

- People with insomnia symptoms exhibit attention biases to sleep-related items.
- These biases have been observed with highly controlled stimuli or contrived scenes.
- This study investigates such biases during the viewing of beds in natural scenes.
- People with insomnia symptoms demonstrated attention retention but not capture by beds.
- A sleep threat interpretation of these findings is proposed speculatively.

Abstract

Attention biases to sleep-related stimuli are held to play a key role in the development and maintenance of insomnia, but such biases have only been shown with controlled visual displays. This study investigated whether observers with insomnia symptoms allocate attention to sleep-related items in natural scenes, by recording eye movements during free-viewing of bedrooms. Participants with insomnia symptoms and normal sleepers were matched in their visual exploration of these scenes, and there was no evidence that the attention of those with insomnia symptoms was captured more quickly by sleep-related stimuli than that of normal sleepers. However, the insomnia group fixated bed regions on more trials and, once fixated on a bed, also remained there for longer. These findings indicate that sleep stimuli are particularly effective in retaining visual attention in complex natural scenes.

Keywords: attention, insomnia symptoms, natural scenes, eye movements, fixation

Introduction

Insomnia is common, with 6-10 percent meeting the criteria for insomnia disorder in the general population (LeBlanc et al., 2009; Morin & Benca, 2012). The condition negatively impacts on cognitive functioning (e.g., Kyle, Espie, & Morgan, 2010; Kyle, Morgan, & Espie, 2010) and mental health (e.g., Baglioni et al., 2011; Baglioni et al., 2010). Theories of insomnia suggest that attention biases towards disorder-relevant stimuli play a key role in its maintenance, by potentiating cognitive arousal and driving sleep intention and effort (Espie et al., 2006; Harvey, 2002). Evidence of such biases comes from experimental tasks in which sleep-related words and objects are presented in attention orienting paradigms. For example, such biases have been demonstrated in change detection paradigms, in which two near-identical images flicker back and forth while one scene element is changing (Jones et al., 2005; Marchetti et al., 2006). In this paradigm, observers with insomnia detect changes to sleep-related items, such as a bed or a pillow, faster than good sleepers. Similar effects have been observed in studies using modified Stroop (e.g., Spiegelhalder et al., 2008) and Posner tasks (e.g., Woods et al., 2009).

While previous studies have demonstrated attention biases to sleep-related items in insomnia, these paradigms rely on highly controlled visual displays (e.g., Spiegelhalder et al., 2008; Woods et al., 2009) or contrived visual scenes (e.g., Jones et al., 2005; Marchetti et al., 2006). Consequently, it remains unresolved whether observers with insomnia also allocate attention to sleep-related items in more natural displays, comprising scenes that might be encountered in everyday life outside of the laboratory. In addition, previous studies are limited in that the methods employed provide only a "snapshot" of the dynamic attentional process (Armstrong & Olatunji, 2012), by terminating measurement upon participants' responses. The current study therefore investigated whether similar attention biases are observed with natural

scenes, and the technique utilised allowed us to address whether these biases persist over more extended intervals.

For this purpose, participants with insomnia symptoms and normal sleep viewed a series of indoor scenes while their eye-movements were recorded in a free-viewing task. Images of living rooms, offices and kitchens served as filler items, while we examined the extent to which observers fixated sleep-related content in bedroom scenes. The aim here was to determine whether those with insomnia symptoms would show increased attention towards sleep-related stimuli, as indexed by earlier and more frequent fixations on beds. In particular, we hypothesised that there would be an attentional bias in the insomnia symptoms group, evidenced by a greater number of fixations to beds (mean total number of fixations; fixations to first look; percentage trials on which regions of interest (ROIs) fixated; percentage fixations on ROIs; percentage revisits to ROIs) and time spent on these regions (time to first look at ROIs; retention time on ROIs) of scenes in comparison to the normal sleepers group.

Method

Participants

This study was approved by the Ethics Committee of the School of Psychology at the University of Glasgow. Forty-one volunteers from the University's participant pool, which includes student and non-student volunteers, participated in return for a small fee. The group of normal sleepers (N = 21) and those with insomnia symptoms (N = 20) were of similar mean age (22.3 years, SD = 3.9 vs. 23.1 years, SD = 4.2) and sex composition (15F/6M vs. 13F/7M).

Pre-screen and scene free-viewing task

Participants responded to an email sent to the School of Psychology research participant pool. We recruited participants who reported insomnia symptoms and normal sleep, which was assessed by the screening question "Insomnia is a difficulty with getting to sleep, maintaining sleep, early morning awakenings, or non-restorative sleep, which adversely affects your daytime functioning. Do you think that you have insomnia?", as well as by responses to two screening questionnaires (see Sleep Measure subsection for cut-offs). Participants were then invited to the laboratory to take part in an eye-tracking experiment on scene perception, but were kept naïve to the full purpose of the experiment until the end. To record observers' natural interest in sleep-related content in scenes, a free viewing paradigm was used so as not to constrain spontaneous eye movement patterns. Thus, participants were simply instructed to view a set of scene images as they naturally would (for similar approaches, see Attard-Johnson, Bindemann, & O Ciardha, 2016; Bindemann, Scheepers, & Burton, 2009).

Photographs of 48 indoor scenes served as stimuli for this eye-tracking task. These scenes were photographed by the authors or taken from internet image searches and comprised 12 pictures each of bedrooms, living rooms, offices and kitchens. These photographs were presented at a size of 1024 (W) x 768 (H) pixels at a screen resolution of 66 ppi on a 21 in. monitor. Living room, office and kitchen scenes served as filler items to disguise the task aims, whereas bedroom scenes served to measure visual interest in beds, which functioned as sleep-related target items. Example stimuli are depicted in Figure 1.

These stimuli were displayed in a randomised order using SR-Research ExperimentBuilder software (version 1.1.0) at a viewing distance of 85 cm, which was held constant by means of a chinrest. Eye movements were tracked with an EyeLink 1000 desk-mounted eye-tracking system running at 500 Hz sampling rate. Viewing was binocular, but only

the participants' left eye was tracked, which was calibrated using the standard Eyelink procedure. Thus, participants fixated an initial series of nine target points on the display monitor. Their accuracy was then validated against a second series of nine fixation targets. Calibration was repeated if poor measurement accuracy was indicated (i.e., a gaze position accuracy of < 0.5°)

In the experiment, each trial began with a central fixation dot, which allowed for drift correction. This was followed by a scene stimulus, which was displayed for 5000 milliseconds. This display duration is similar to other eye-tracking studies with static scene images (e.g., Attard-Johnson, Bindemann, & O Ciardha, 2016) and allows for approximately 15 fixations (based on an average fixation duration lasting 200-300 ms, see Rayner, 1998), which is sufficient time to scan the entire scene.

Sleep measures

The two sleep groups (normal sleepers and insomnia symptoms) were confirmed via two pre-test questionnaires:

1. The Pittsburgh Sleep Quality Index (PSQI) measures sleep quality over the past month, with scores ranging from 0-21 (Buysse et al., 1989). The PSQI is widely used to reliably measure sleep quality and validity has been demonstrated in various populations including healthy controls, patients with cancer, patients with depression and patients visiting sleep clinics (Carpenter & Andrykowski, 1998). A score of 7 or higher was used to define insomnia symptoms, while normal sleepers were defined by a score of 6 or less. This cut-off score is associated with improved balance of sensitivity to specificity (Backhaus et al., 2002); and a

recent study finds >6 to be optimal in detecting sleep complaints in students (Manzar et al., 2015).

2. The Insomnia Severity Index (ISI) (Bastien, Vallieres, & Morin, 2001) is commonly utilised to reliably detect cases of insomnia, and reliability and validity have been reported in insomnia populations. The ISI was used to quantify participants' level of insomnia symptoms on a 0-21 point scale. In line with previous studies, scores below 8 were used to identify normal sleepers, and participants with insomnia symptoms identified as those scoring 8 or higher (Ree, Pollitt, & Harvey, 2006; Ellis, Gardani, & Hogh, 2010).

After the eye-tracking task, a series of sleep-related measures were also administered to confirm the two sleep groups (normal sleepers and insomnia symptoms):

1. The consensus sleep diary, developed by expert consensus (Carney et al., 2012) was used to assess participants' sleep on test days, and is the "gold standard" for sleep assessment. Descriptively, this measure confirmed that participants had achieved at least five hours time in bed on test days.

2. The sleep disorders algorithm from the British Association for Psychopharmacology consensus statement (see Wilson et al., 2010) was used to screen for sleep disorders other than insomnia (e.g., narcolepsy, sleep breathing disorder, parasomnias). None of the participants had evidence of any other sleep disorder, but all insomnia symptom participants endorsed an insomnia complaint.

3. The Morningness-Eveningness Questionnaire (Horne & Ostberg, 1976) assesses diurnal preference with scores of 70-86 indicating a definite morning type, 59-69 a moderate morning type, 42-58 neither type, 31-41 a moderate evening type, and 16-30 a definite evening type.

4. The Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) was used to assess levels of anxiety and depression symptoms amongst both groups. Reliability, validity and factor structure of the measure have been confirmed (Bjelland et al., 2002). Scores of 0-7 are indicative of no significant mood disruption, 8-10 suggests subclinical mood disruption, and 11 or higher indicate clinical levels of mood disruption.

Characterisation of Sleep Groups

To be included in the insomnia symptoms group, each individual had to self-report an insomnia complaint, and score above threshold on both the ISI and PSQI and not endorse any other sleep disorder. Each individual included in the normal sleeper group did not endorse an insomnia complaint and scored below threshold on both the ISI and PSQI. Data from three additional individuals were excluded due to experimenter error or participant non-compliance.

Results

Sleep measures

Consistent with group allocation, people with insomnia symptoms (IS) scored above threshold and higher than normal sleepers (NS) on both the PSQI (IS M = 11.2, SD = 2.3 vs. NS M = 3.3, SD = 1.3), $t(39) = 13.59$, $p < 0.001$, *Cohen's d* = 4.22, and the ISI (IS M = 15.0, SD = 2.5 vs. NS M = 2.7, SD = 1.8), $t(39) = 17.97$, $p < 0.001$, *Cohen's d* = 5.65. In addition, none of the participants reported evidence of any other sleep disorder. Adequate opportunity for sleep was validated by a test-day time in bed of greater than five hours.

In addition, MEQ scores indicated that insomnia symptom participants were more inclined towards Eveningness than normal sleepers (IS M = 40.6, SD = 10.3 vs. NS M = 48.8,

SD = 8.9), $t(39) = 2.72$, $p < 0.05$, *Cohen's d* = 0.85. HADS scores also revealed higher levels of anxiety in insomnia symptoms participants than normal sleepers (IS M = 8.9, SD = 4.3 vs. NS M = 5.7, SD = 2.6), $t(39) = 2.88$, $p < 0.01$, *Cohen's d* = 0.90, and higher levels of depression (IS M = 6.5, SD = 3.2 vs. NS M = 2.6, SD = 2.1), $t(39) = 4.69$, $p < 0.001$, *Cohen's d* = 1.44.

Eye movement analysis

Eye movements were pre-processed by merging fixations of less than 80 ms with the preceding or following fixation if that fell within half a degree of visual angle (for similar approaches, see Attard & Bindemann, 2013; Bindemann, Scheepers, Ferguson, & Burton, 2010). In addition, any fixations that fell outside the dimensions of the display monitor or that were obscured by blinking were excluded. To examine the viewing behaviour of insomnia participants and good sleepers, a number of measures were then calculated. These comprised (1) the total number of fixations that were made on each trial, the time taken to first locate the bed regions in the scenes in (2) fixations and (3) milliseconds, (4) the percentage of scenes on which beds were fixated, (5) the percentage of fixations that landed on the bed regions, (6) the retention time on the bed regions, and (7) the number of revisits on the bed regions after these had already been fixated. All of the measures had good internal reliability, with Cronbach's α ranging from 0.764 to 0.972 across measures (mean $\alpha = 0.906$).

The total number of fixations that were made on each trial was closely matched for insomnia symptoms participants and normal sleepers (IS M = 14.7, SD = 1.8 vs. NS M = 15.0, SD = 1.7), $t(39) = 0.61$, $p = 0.55$, *Cohen's d* = 0.17, which indicates that both groups of observers were similarly active in exploring the visual scenes. The time taken to first locate the bed regions in these scenes was also comparable across groups. On average, both groups first

fixated the beds with only the fifth fixation (IS M = 5.0, SD = 1.1 vs. NS M = 5.1, SD = 1.3), $t(39) = 0.37$, $p = 0.71$, *Cohen's d* = 0.08, or after approximately 1.3 seconds (IS M = 1331 ms, SD = 340 vs. NS M = 1326 ms, SD = 411), $t(39) = 0.40$, $p = 0.97$, *Cohen's d* = 0.01. Thus, these groups appear to behave similarly in terms of the speed with which attention is first allocated to beds in scenes.

However, groups differed in the extent to which the bed regions were attended. Participants with insomnia symptoms fixated the bed regions in a greater percentage of scenes than normal sleepers (IS M = 85.4%, SD = 12.6 vs. NS M = 77.8%, SD = 12.2), although this effect was not statistically significant, $t(39) = 1.97$, $p = 0.06$, *Cohen's d* = 0.61. In addition, the insomnia group directed a greater percentage of fixations at the bed regions within trials (IS M = 19.4%, SD = 6.2 vs. NS M = 16.2%, SD = 2.6), $t(39) = 2.19$, $p < 0.05$, *Cohen's d* = 0.67, and, once fixated on a bed, remained there for longer (IS M = 698 ms, SD = 274 vs. NS M = 549 ms, SD = 150), $t(39) = 2.17$, $p < 0.05$, *Cohen's d* = 0.67. Thus, insomnia participants fixated bed regions more frequently in trials, and remained fixated on these regions longer. Finally, we also analysed whether participants with insomnia symptoms were more likely to revisit the bed regions in a scene after these had already been fixated. Across trials, the mean number of such revisits was low and comparable for insomnia symptom participants and normal sleepers (IS M = 0.51 SD = 0.25 vs. NS M = 0.54 SD = 0.25), $t(39) = 0.36$, $p = 0.72$, *Cohen's d* = 0.12.

Analysis of filler scenes

Additional analyses were performed to compare viewing behaviour for bedrooms with the filler scenes (offices, living rooms, kitchens). As an overall measure of viewing behaviour to the entire scene stimuli, the total number of fixations that were made to bedroom scenes (M =

14.8, SD = 1.7), living rooms (M = 15.1, SD = 1.7), offices (M = 14.8, SD = 1.9), and kitchens (M = 15.1, SD = 1.6) were compared first. A 2 (IS vs. NS) x 4 (room type) repeated measures ANOVA of this data did not show a main effect of group, $F(1,39) = 0.84$, $p = 0.37$, *partial η2* = 0.02, or an interaction between factors, $F(3,117) = 0.31$, $p = 0.82$, *partial η2* = 0.01. A main effect of room was found, $F(3,117) = 3.46$, $p < 0.05$, *partial η2* = 0.08, but Bonferroni-corrected pairwise comparisons did not reveal differences between conditions, all original *ps* ≥ 0.09.

In a next step, we explored whether some areas within the filler scenes might exhibit similar properties to beds in people with insomnia symptoms. Specifically, the areas occupied by sofas and armchairs in the living room scenes and the desks in the office scenes were also coded as potential sleep-interest ROIs. The kitchen stimuli did not contain a similar ROI that was consistently present across scenes and were therefore unsuitable for this analysis. We then computed 2 (IS vs. NS) x 3 (ROI: beds, sofas, desks) ANOVAs for all eye movement measures. Note that these analyses revealed main effects of ROI for all measures, all *Fs*(2,78) ≥ 18.77, all *ps* < 0.001, all *partial η2* ≥ 0.33. However, as these different ROIs were not equated for factors such as size, colour and location, the following analyses focus on the main effect of group and the interaction of group and ROI.

Analysis of the number of fixations and the time in milliseconds that was required to first fixate the ROIs, as well as the percentage of scenes on which the ROIs were fixated, ANOVA did not reveal main effects of sleep group or interactions between group and ROI, all *Fs*(1,39) ≤ 1.75, *ps* ≥ 0.19, all *partial η2* ≤ 0.04. In contrast, the percentage of fixations that were directed at the ROIs in trials did not show a main effect of group, $F(1,39) = 0.79$, $p = 0.38$, *partial η2* = 0.02, but revealed an interaction between factors, $F(2,78) = 5.83$, $p < 0.01$, *partial η2* = 0.13. Consistent with our primary analyses, simple main effects showed that insomnia symptom

participants directed more fixations at beds than normal sleepers (IS M = 19.4%, SD = 6.2 vs. NS M = 16.2%, SD = 2.6), $F(1,39) = 4.78$, $p < 0.05$, *partial η2* = 0.11, whereas these scores were more evenly matched for sofas (IS M = 11.0%, SD = 5.2 vs. NS M = 13.4%, SD = 2.9), $F(1,39) = 3.31$, $p = 0.08$, *partial η2* = 0.08, and desks (IS M = 9.0%, SD = 3.3 vs. NS M = 7.6%, SD = 3.0), $F(1,39) = 1.93$, $p = 0.17$, *partial η2* = 0.05. Once fixated, insomnia participants also remained on all ROIs for longer (IS M = 556 ms, SD = 144 vs. NS M = 464 ms, SD = 100), $F(1,39) = 5.64$, $p < 0.05$, *partial η2* = 0.13, but this effect was not accompanied by an interaction between factors, $F(2,78) = 1.45$, $p = 0.24$, *partial η2* = 0.04.

The revisits to the ROIs, once these had already been fixated, were also examined. These did not reveal a main effect of sleep group, $F(1,39) = 1.42$, $p = 0.24$, *partial η2* = 0.04, or an interaction between factors, $F(2,78) = 1.32$, $p = 0.27$, *partial η2* = 0.03.

Influence of anxiety and depression

There were no significant correlations of anxiety (*rs* = -0.256 to 0.236, all $ps \geq 0.11$) or depression (*rs* = -0.159 to 0.179, all $ps \geq 0.26$) with any of the eye-tracking measures, indicating that anxiety and depression did not contribute towards results.

Discussion

Previous studies have demonstrated attention biases to sleep-related items in observers with insomnia, but these paradigms either utilised highly controlled visual displays (e.g., Spiegelhalder et al., 2008; Woods et al., 2009) or contrived visual scenes (e.g., Jones et al., 2005; Marchetti et al., 2006). In the current study, we examined whether observers with insomnia

symptoms allocate attention to sleep related items in complex natural scenes that might be encountered in everyday life outside of the laboratory.

For this purpose, we compared two groups of observers, comprising normal sleepers and people with insomnia symptoms, whose sleep quality was assessed with a battery of established measures. Those exhibiting insomnia symptoms were investigated since attention bias has previously been observed in both poor sleepers and clinically-defined insomnia patients (Harris et al., 2015). Of specific interest in the current study was whether these groups differed in the allocation of attention around sleep-related scenes. Both groups were matched in the number of fixations around bedroom scenes, which indicates that they were similarly active in the visual exploration of these stimuli. The time delay to first fixate beds in these scenes was also comparable across groups. In contrast to studies that have demonstrated attention capture by sleep items with simple artificial displays (cf. Harris et al., 2015), the current findings therefore indicate that the attention of insomnia symptom participants is not captured more effectively than that of normal sleepers when sleep-related stimuli are embedded in natural scenes.

Crucially, however, participants with insomnia symptoms differed from normal sleepers in the extent to which attention was allocated to the beds, by directing a higher percentage of fixations at these regions. This behaviour does not reflect a tendency to revisit bed regions intermittently after other scene content has also been viewed, but rather prolonged attentional engagement by bed stimuli once they are fixated. These findings converge with previous studies that have demonstrated attention retention for sleep-related stimuli in observers with insomnia disorder (Harris et al., 2015). In contrast to previous studies, these effects are observed here with sleep-related stimuli (i.e. beds) that are positioned in naturalistic locations in complex everyday scenes.

We also included additional analysis for the living room and office filler scenes, to compare viewing behaviour toward beds with sofas and desks. We report this post hoc analysis tentatively as these ROIs were not matched for a range of factors, such as their size, location and salience. This analysis revealed that participants with insomnia symptoms directed a greater percentage of fixations at beds compared to normal sleepers, whereas the behaviour of these groups was more closely matched for sofas and desks. The analysis of the filler scenes therefore provides converging evidence that participants with insomnia symptoms direct more attention at sleep-related items (beds) than normal sleepers in complex natural scenes. However, once fixated, participants with insomnia symptoms remained focused on all of these stimuli for longer. This could suggest that sofas and desks are also considered to be sleep-related by these observers, perhaps because these objects present potential rest places.

We note that the insomnia symptom participants in the current study not only fixated sleep-related stimuli for longer, but also reported elevated levels of anxiety on the HADS. Whereas this might converge with reports that anxious individuals tend to fixate threatening stimuli for longer (Armstrong & Olatuji, 2012; Felmingham et al., 2011), none of the eye-tracking measures correlated with anxiety or depression. It has also been suggested that sleep-related stimuli might trigger a craving in insomnia symptom participants. Although the typical response to craving is the approach of rewards (Shechner et al., 2012), we found no evidence that insomnia symptom participants were quickly drawn to the bed regions in scenes. Therefore, it is unclear how threat- or craving-related interpretations can account for the current pattern of results. However, the current study was not designed to investigate such interpretations directly.

There are a number of limitations to the study, which should be considered when designing extensions to the work. First, the sample size is small, although similar to that used in

a previous study utilising eye tracking in subjects with insomnia symptoms (Woods et al., 2013). Additionally, while subjects in the insomnia group demonstrated insomnia via the validated ISI, and matched age characteristics of previous samples (Woods et al., 2009), they represented a relatively narrow age range and thus the results would be supported by further work including a more general cross-section of the population. While the sleep measures included in our work are widely used to characterise subjects into insomnia symptoms and normal sleeper groups (Harris et al., 2015) there was no objective measure of sleep within this study, so further work would benefit such an inclusion. Finally, it is also possible that attentional bias to beds could be caused by other factors, such as an interest in sexual activity, or indeed, sexual trauma.

Compared to most previous attention bias work in insomnia, the method of eye tracking employed here affords the opportunity of a more direct measure of attention (Harris et al., 2015). Further, examining the pattern of viewing in a more natural scene, where the visual environment is more complex, has allowed us to confirm that sleep stimuli are particularly effective in retaining attention of those with insomnia symptoms. Going forward, the challenge for future studies is to determine the relevance and importance of attention bias to the development and/or maintenance of chronic insomnia.

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FIGURE 1. Examples of bedroom scenes (top row), and the coded bed regions for eye movement analysis (middle row). An office, living room and kitchen filler scene are also shown (left to right, bottom row).