

Assessing the Therapeutic Potential of Targeted Attentional Bias Modification for Insomnia Using Smartphone Delivery

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Supplementary Online Material

Creation of experimental word stimuli

Research assessing the presence of attentional bias in insomnia has consistently employed paired word stimuli that contain a threatening member, which communicates a meaning relevant to the concerns of those with sleep disturbance, and an emotionally neutral stimulus member (see [1]). In line with this, we included 48 threatening sleep-related words characteristic of pre-sleep worry thoughts, paired with neutral words matched for length and spoken frequency [2] for the purpose of modification and assessment of attentional bias. The threat words were selected from an initial pool of 96 candidate words. These words were generated on the basis of three factors identified by Wicklow and Espie [3] as core themes relevant to pre-sleep worry consistently reported by individuals with insomnia: active problem solving (e.g. thoughts about the negative consequences of poor sleep), present-state monitoring (e.g. thoughts about bodily functions), and reactivity to external stimuli (e.g. thoughts about environmental factors disturbing sleep). All 96 candidate words were rated by 12 independent judges using a 7-point scale on emotional valence, from 1 (Very negative) to 7 (Very positive) and relatedness to sleep concerns, from 1 (Not at all) to 7 (Extremely). The final selected threat words were rated to be strongest in negative valence ($M = 2.35$, $SD = 0.78$) and most relevant to sleep concerns ($M = 4.67$, $SD = 0.93$). The word pairs were randomised and divided into two separate stimulus subsets (Subset A and Subset B). For half the participants in each condition Subset A was used in the training/control component and Subset B was used in the assessment component of the task, while the remaining participants received the reverse allocation. The use of different stimuli in the training and assessment components ensures that any change in attentional bias can be attributed to the class of stimulus and not to specific stimuli themselves. These stimuli are provided in Supplementary Table 1.

Probe task parameters

We sought to use an attentional probe training paradigm as this type of task has been successfully employed in past research to modify patterns of biased attention for threat [4, 5], and it has been used to establish the presence of attentional bias for threat in insomnia [1]. Trials on the probe task all shared a common structure. Each trial began with a white fixation cross (+) on a black background presented in the center of the screen for 500ms. Two words then appeared in white text for 500ms, one threat and one neutral, vertically aligned and separated by 25mm. Immediately following the termination of this display a visual probe comprising two small red dots

Supplementary Table 1. Word stimuli employed in the attentional probe task. The threat word is the first member of each pair

Stimulus Word Pairs	
Subset A	Subset B
Ache [‡] - Melt	Lazy [‡] - Hint
Afraid [‡] - Artist	Lethargy* - Teaspoon
Agitated* - Carriers	Medication - Bottleneck
Alarm~ - Spray	Inept - Sedan
Angry [‡] - Curve	Nightmare [‡] - Volunteer
Anxiety [‡] - Express	Overactive [‡] - Clearances
Confuse - Drawers	Panicky [‡] - Infuser
Conflict [‡] - Advanced	Restless [‡] - Receiver
Delirious [‡] - Fragments	Sad [‡] - Cup
Desperate [‡] - Aesthetic	Sick* - Pull
Disastrous [‡] - Curriculum	Sleepless* - Advisable
Disengaged [‡] - Nonfiction	Sleepy* - Wallet
Disorder [‡] - Compost	Sluggish [‡] - Decorate
Distract [‡] - Brochure	Snoring [‡] - Charity
Distress [‡] - Creature	Stress* - Links
Drowsy* - Umpire	Suffer [‡] - Branch
Exhausted* - Developed	Tense [‡] - Trick
Fatigue* - Passive	Time [‡] - Look
Hopeless [‡] - Borrowed	Tired [‡] - Plain
Illness* - Mustard	Unpleasant [‡] - Expedition
Inadequate [‡] - Initiative	Wakeful [‡] - Trolley
Irrational [‡] - Flashlight	Work* - Life
Irritable [‡] - Appliance	Workload* - Handbags
Jittery [‡] - Thermos	Worry [‡] - Theme

*Active problem-solving, [‡]Present-state monitoring, ~Environmental reactivity [cf. 3]

oriented either horizontally (..) or vertically (:) appeared in the location vacated by one of the words. Threat word position (upper/lower) and probe type (horizontal/vertical probe) was randomised within the constraint that an equal number of each probe type was presented, and the threat word appeared equally often in the upper and lower position. Participants discriminated probe identity by tapping the corresponding horizontal or vertical arrow icon at the bottom of the display (see Figure 1).

Across the 384 trials completed on Task Completion Days 1-5 before bed each night, for 288 trials (12 repetitions of 24 words pairs), the position of the probe was contingent on the allocated condition. For those in the ABM condition, visual probes consistently replaced neutral words to encourage attentional avoidance of threat. Conversely, for those in the control condition, the task was identical in all



Fig 1. Example trial of the attentional probe task delivered via iPhone.

aspects with the exception that visual probes replaced threat and neutral words with equal frequency on each trial. The remaining 96 trials in each condition (4 repetitions of 24 words pairs) were attentional assessment trials where probes replaced the threatening and neutral member of word pairs with equal frequency. While a continuous block of attentional assessment trials permits a discrete period of attentional assessment, there is also the possibility that such a discrete block of trials can potentially disrupt/compromise an acquired pattern of attentional selectivity and any associated effects. As such, and consistent with the approach of a number of previous studies [e.g. 6, 7, 8] assessment trials were incorporated into the training trials by randomly dispersing the 96 attentional assessment trials in the latter half of the training trials. Reaction time data derived from the attentional probe assessment trials was prepared in a manner consistent with previous studies [9, 10]. Specifically, to limit the influence of outlying data, trials with incorrect responses (4.16% of trials) or latencies less than 200ms (0.25% of trials) or greater than 2000ms (1.52% of trials) were removed.

Electrophysiological sleep monitor

We employed a commercially available electro-physiological sleep monitoring system (EPSM; Zeo, Inc., Newton, MA, USA). The EPSM uses dry silver-coated fabric to collect electrophysiological signals from the forehead with a single bi-polar channel located at approximately Fp1-Fp2 [11]. Research comparing sleep measures derived from this EPSM device with polysomnography has revealed a high degree of concordance, particularly in relation to sleep and

wakefulness measures [92.6% and 91.1% respectively; 12].

Experimental Procedure

Prior to the commencement of the study, participants were told only that the study sought to examine the relationship between sleep disturbance, worry, and patterns of cognitive information processing and were not alerted to the presence of the alternative experimental conditions. The attentional probe task application was installed on participants' iPhones, along with links to the pre-sleep and sleep diary questionnaire measures. Participants were given detailed instructions on how to access these measures and how to complete the attentional probe task. They then completed 96 attentional probe assessment trials. Lastly, participants were provided instructions in the use of the electrophysiological sleep monitor (EPSM) and observed the correct way to fit the device, charge the headband, and how to set up the bedside base station. Participants were instructed that on all days, prior to sleep each night they should complete the pre-sleep questionnaire via the app, wear the EPSM from the moment they intended to go to sleep until morning, and upon waking update their daily sleep diary. In addition, they were instructed to complete the attentional probe task prior to the pre-sleep questionnaire measure each night from the third to the final day (Task Completion Days 1-5). At the follow-up session (8 days after the pre-assessment) participants completed the post-assessment questionnaire measures, the EPSM system was returned, and the attentional probe task application was removed from participants' iPhones. In addition, participants were debriefed about the purpose and design of the study.

Results

The following includes graphical representations of key findings described in the main manuscript.

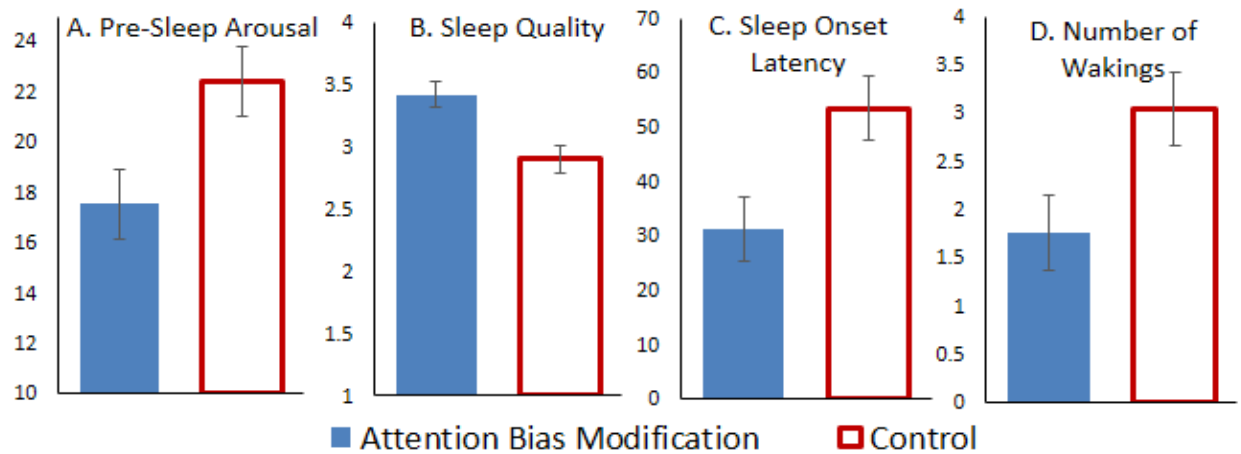


Fig 2. Daily sleep measures for participants in the Attentional Bias Modification and Control conditions showing group differences on the pre-sleep arousal scale (A: $t=2.45, p=.02, d=0.68$), self-rated sleep quality (B: $t=3.34, p<.01, d=0.60$), sleep-monitor assessed sleep onset latency in minutes (C: $t=2.65, p=.01, d=0.64$) and sleep-monitor assessed number of wakings (D: $t=2.34, p=.02, d=0.78$).

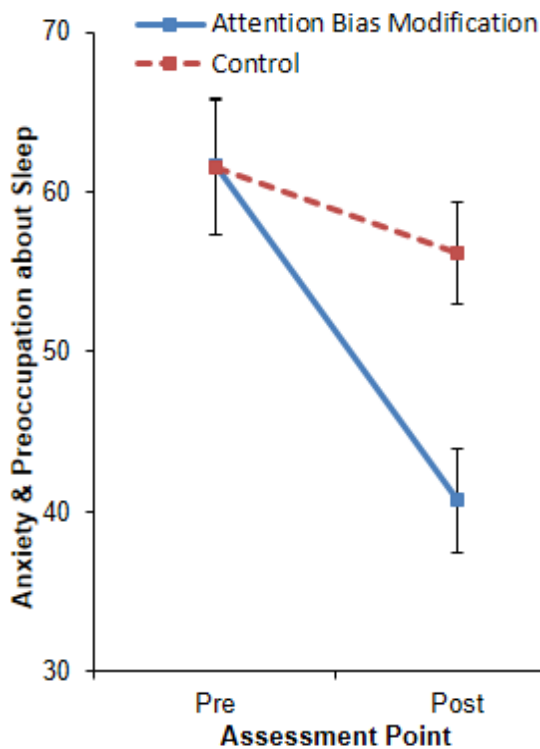


Fig 3. Change in sleep-related anxiety from pre-assessment to post-assessment for the Attentional Bias Modification and Control groups. Pre-assessment between group comparison: $t=0.02, p=.98, d=0.01$; post-assessment between group comparison $t=3.34, p<.01, d=1.11$.

Supplementary Discussion

Assessment of Attentional Bias

Unlike measures of sleep quality, pre-sleep arousal, sleep onset latency, and number of wakings, we did not also observe consistent change in measures of attentional bias in line with each condition. While it is possible that this pattern of findings represents a genuine absence of bias change, the consistent pattern of effects across a number of separate measures suggests that ABM was having the intended effect on sleep and arousal. These effects therefore provide support for the alternative possibility, that the intended bias change may have been achieved but not detected.

Of relevance to this is the fact that attentional bias was assessed using smartphones. The use of smartphones in the current study provided a convenient and highly accessible method of delivering ABM at the precisely intended time. However, greater flexibility in task delivery comes at the potential expense of greater precision for assessing attentional bias. ABM induced changes in attentional bias commonly occur within the range of 10-20 milliseconds [9, 13]. Computer-based tasks delivered in laboratory settings allow for precise control across a range of factors relevant to the assessment of attentional bias (e.g. stimulus viewing distance, reaction time measurement, etc.). As smartphones have not been validated as a means of assessing patterns of biased attention, this could potentially account for our failure to confirm attentional bias change in line with the assigned attentional training condition. To permit more precise assessment of attentional bias future research could employ pre and post-intervention computer-based assessments to confirm changes in attentional bias. However, it is possible that if the attention bias modification task resulted in only very acute, rather than enduring change in attentional bias for sleep-related threat, then lab-based assessment may not show a between-group change in

attentional bias, even if such a change is achieved using the iPhone ABM task. For this reason it may be ideal to include a comparison computer-based pre-sleep training and assessment of attentional bias to confirm change in attentional bias in response to the ABM task.

Effects on Self-Report and Object Sleep Measures

While the positive impact of ABM was demonstrated on objective measures obtained from sleep monitors and from participants' ratings of sleep quality in general, there was no observed effects on self-report measures of sleep onset or frequency of waking. However, as previously noted, the tendency towards misperception of sleep outcomes characteristic of poor sleepers [14] means that such self-report measures requiring retrospective estimates of the time taken to lose consciousness, or the frequency of waking, are unlikely to be reliable indices of sleep. Indeed, the presence of significant effects on both objective measures obtained from sleep monitors, and on self-report measures of arousal and sleep quality provides encouragement that ABM was having the intended effect. These findings are particularly noteworthy given the brief implementation of ABM and the non-pharmacological nature of the intervention, and suggest that the ABM procedure was successful in briefly reducing cognitive arousal symptoms, allowing greater ease of sleep onset and more restful sleep.

Supplementary References

1. Harris, K., et al., Sleep-Related Attentional Bias in Insomnia: A State-of-the-Science Review. *Clinical Psychology Review*, 2015.
2. Wilson, M., MRC Psycholinguistic Database: Machine-usable dictionary, version 2.00. *Behavior Research Methods, Instruments, & Computers*, 1988. 20(1): p. 6-10.
3. Wicklow, A. and C. Espie, Intrusive thoughts and their relationship to actigraphic measurement of sleep: towards a cognitive model of insomnia. *Behaviour research and therapy*, 2000. 38(7): p. 679-693.
4. Amir, N., et al., Attention modification program in individuals with generalized anxiety disorder. *Journal of Abnormal Psychology*, 2009. 118(1): p. 28-33.
5. MacLeod, C., et al., Selective attention and emotional vulnerability: Assessing the causal basis of their association through the experimental manipulation of attentional bias. *Journal of Abnormal Psychology*, 2002. 111(1): p. 107-123.
6. Krebs, G., C.R. Hirsch, and A. Mathews, The effect of attention modification with explicit vs. minimal instructions on worry. *Behaviour Research and Therapy*, 2010. 48(3): p. 251-256.
7. Wells, T.T. and C.G. Beevers, Biased attention and dysphoria: Manipulating selective attention reduces subsequent depressive symptoms. *Cognition and Emotion*, 2010. 24(4): p. 719-728.
8. Hayes, S., C.R. Hirsch, and A. Mathews, Facilitating a benign attentional bias reduces negative thought intrusions. *Journal of Abnormal Psychology*, 2010. 119(1): p. 235-240.
9. Amir, N., et al., Attention training in individuals with generalized social phobia: A randomized controlled trial. *Journal of Consulting and Clinical Psychology*, 2009. 77(5): p. 961-973.
10. Clarke, P.J.F., et al., The Causal Role of the Dorsolateral Prefrontal Cortex in the Modification of Attentional Bias: Evidence from Transcranial Direct Current Stimulation. *Biological Psychiatry*, 2014. 76(12): p. 946-952.
11. Kelly, J.M., R.E. Strecker, and M.T. Bianchi, Recent developments in home sleep-monitoring devices. *ISRN neurology*, 2012. 2012: p. 768794-768794.
12. Shambroom, J.R., S.E. Fabregas, and J. Johnstone, Validation of an automated wireless system to monitor sleep in healthy adults. *Journal of Sleep Research*, 2012. 21(2): p. 221-230.
13. Amir, N., et al., The effect of a single-session attention modification program on response to a public-speaking challenge in socially anxious individuals. *Journal of Abnormal Psychology*, 2008. 117(4): p. 860-868.
14. Means, M.K., et al., Accuracy of sleep perceptions among insomnia sufferers and normal sleepers. *Sleep Medicine*, 2003. 4(4): p. 285-296.