Tired and lack focus? Insomnia increases distractibility

Abstract

Chronic insomnia is associated with subjective daytime cognitive dysfunction, but objective corroborative data is often lacking. In this study, we use Perceptual Load Theory (Lavie, 1995) to objectively assess distractibility in participants with insomnia (N = 23) compared with age and sex matched controls (N = 23). Following overnight supervised sleep observation, all participants completed a selective attention task which varied in the level of perceptual load and distractor congruency. The insomnia group were found to be more distracted than controls, whereas their selective attention mechanism appeared to be intact, with reduced distractor processing under high load for both groups. Insomnia symptom severity was positively correlated with participant distractibility. These findings suggest that there are insomnia-related daytime cognitive impairments that are likely to arise from compromised cognitive control rather than an ineffective selective attention mechanism. This task may be clinically useful in assessing daytime impairments, and potentially treatment response, in those with insomnia.

Key Words

Distraction, Insomnia, Perceptual Load, Selective Attention, Sleep

Public Significance Statement

Patients with insomnia report problems with daytime concentration. Using an objective selective attention task, we show people with insomnia are more distractible at low levels of perceptual load, but their selective attention mechanism is intact.

Introduction

Insomnia is the most common sleep disorder affecting approximately 10% of the adult population as a chronic condition (Ohayon, 2002; Perach et al., 2018; Roth & Roehrs, 2003). The disorder is characterised by difficulty with either getting to sleep (initiation), staying asleep (maintenance), and/or early morning awakening with an inability to return to sleep, leading to an overall dissatisfaction with either sleep quantity or quality. To be classified as chronic, insomnia symptoms must also be present for at least three nights per week for a minimum of three months (DSM-5; American Psychiatric Association, 2013; ICSD-3; American Academy of Sleep Medicine, 2014). The complaint of night time difficulties must also be accompanied by at least one report of daytime performance impairment in, for example, a social, occupational or educational context (DSM-5; American Psychiatric Association, 2013).

While research has established links between insomnia and increased morbidity and mortality (Leger et al., 2014; Sivertsen et al., 2014); poor quality of life (Kyle, Espie, & Morgan, 2010); and a spectrum of affective (Baglioni et al., 2011; Kyle, Beattie, Spiegelhalder, Rogers, & Espie, 2014; Spiegelhalder, Regen, Nanovska, Baglioni, & Riemann, 2013) and cardiovascular conditions (Sofi et al., 2014; Spiegelhalder, Scholtes, & Riemann, 2010), related cognitive and perceptual deficits have received less attention (see Fortier-Brochu, Beaulieu-Bonneau, Ivers, & Morin, 2012). Given daytime symptoms, particularly the lack of concentration (i.e. the ability to focus attention on a task while ignoring distraction) is of particular concern to insomnia sufferers (Roth & Ancoli-Israel, 1999), little is known about the effect of insomnia on specific aspects of cognition, such as selective attention and distractibility (Giora, Galbiati, Marelli, Zucconi, & Ferini-Strambi, 2017). Insomnia patients often describe "struggling through the day" (Kyle, Espie & Morgan, 2010) and a reduction in work performance and productivity (Linton & Bryngelsson, 2000). Results from a nationally representative sample of employees in the US found that insomnia was associated with

increased workplace presenteeism (poor concentration and performance while at work) (Kessler et al., 2011) and less overall productivity (Shahly et al., 2012). Insomnia has also been linked to impaired driving performance (Perrier et al., 2014) and road accidents (Garbarino et al., 2017; Leger et al., 2014).

The selective attention mechanism enables people to focus on task relevant information while ignoring task irrelevant distraction (see Driver, 2001 for a review). Perceptual load theory provides a well-established explanation of the way in which this mechanism may operate (see Forster & Lavie, 2015; and Lavie, 2010 for a review). It states that we have a finite perceptual capacity, and that all incoming information (relevant and distracting) is perceived until this capacity has been consumed. That is, when engaged in a task that places few demands on attention (i.e. when the perceptual load of the task is low), irrelevant distractors are perceived and interfere with information processing (e.g. performing a boring task in the office and being distracted by noise from the corridor; see MacDonald & Lavie, 2011). In contrast, when the task at hand places greater demands on our attention (i.e. when the perceptual load of the task is high), the task consumes our processing resources and irrelevant distracting information is filtered from perception (e.g. performing a complex task at work and failing to notice at knock at your office door; see Raveh & Lavie, 2015).

Previous research on the effects of insomnia on selective attention have tended to use the Attention Network Task (ANT) (Li et al., 2016; Perrier, Chavoix, & Bocca, 2015) or variants of sleep-related attentional bias paradigms (Jones, Macphee, Broomfield, Jones & Espie, 2005), which are limited in their use of only single (low) perceptual load conditions. In contrast, Kong, Soon and Chee (2011) investigated distractor (scene) processing in experimentally sleep deprived (SD) participants, while manipulating the perceptual load of an embedded target (face), in a repetition-suppression task. The study did not find increased distractor processing in the SD group relative to the control group (non-sleep-deprived participants), finding instead

that sleep deprived individuals appeared to be processing the distractor scenes to a *lesser* extent than controls. However, there are limitations to this study which restrict the conclusions that can be drawn from these findings. First, as the authors note, their task did not assess how spatially separate distractors *interfere* with task performance, as would be the case for everyday distraction (i.e. an internet pop-up ad interfering with the task of reading a research article, see Forster & Lavie, 2007). Second, the authors used face stimuli as their targets, and recent research has shown that this category of objects constitutes a 'distinct' type of perceptual load which operates out with non-face perceptual processes (see Thoma & Lavie, 2013). Third, this study experimentally induced sleep deprivation in good sleepers, rather than recruiting patients with chronic insomnia, which could limit the generalisability of these findings to those with a clinical diagnosis of chronic insomnia.

Therefore, in the present study, we use a well-established perceptual load task (letter search) with spatially separate distractors which can interfere with the primary task, to assess selective attention and distraction in a sample of patients with clinically diagnosed insomnia and age and sex matched controls. Using the perceptual load framework, we ask three key questions. First, in line with the diagnostic criteria, we assess whether those with insomnia were more distracted compared to controls. Second, we assess whether the selective attention mechanism is intact in patients with insomnia. Third, with the current lack of objective measures for daytime insomnia-related impairments (Fortier-Brochu, Beaulieu-Bonneau, Ivers, & Morin, 2012; Herbert, Kyle, & Pratt, 2018) we determine whether the level of distractibility in the insomnia group correlated with measures of insomnia symptom severity.

Method

Ethical Approval

Ethical approval for this study was granted by the Sydney Local Health District Ethics Committee (Protocol No. X14-0389 & HREC/14/RPAH/517). All patients gave written informed consent. This study was part of a larger Insomnia phenotyping and treatment project (Clinical Trial Registration: Australia New Zealand Clinical Trials Registry (ANZCTR) identification number: 12615000751572). Participant testing occurred either at Woolcock Institute of Medical Research, Sydney or Adelaide Institute for Sleep Health, Adelaide, Australia.

Participant Recruitment

Participants in the insomnia group were recruited from a volunteer database, advertisements posted in sleep clinics and on noticeboards in the local community, and through online recruitment. Participants were directed to a research website which assessed initial eligibility. Participants were assessed using a standardised Insomnia assessment questionnaire, the Insomnia Severity Index (ISI) (Morin, 1993; Morin, Belleville, Bélanger, & Ivers, 2011) and by a semi-structured telephone interview for insomnia (Morin & Espie, 2003). Participants who met initial criteria for insomnia were then invited to take part in a comprehensive clinic-based interview conducted by a tertiary level Sleep Physician (sleep disorder specialist) to confirm the diagnosis of Insomnia Disorder based on DSM-5 (APA, 2013). Specifically, these criteria include difficulty with at least one of the following: initiating, maintaining, or awaking too early from sleep and accompanied by a significant daytime impairment for at least three nights per week, for at least three months. Each participant in the insomnia group also exceeded the clinical threshold for Insomnia Disorder on the Insomnia Severity Index (ISI) (a score $\geq$ 10 for sub-clinical insomnia; Morin, 2011), had poor-sleep quality (>5) from the Pittsburgh Sleep

Quality Index (PSQI) (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Mean scores on these measures are reported in Table 1. Finally, in order to ensure that the Insomnia Disorder was not driven by any extraneous factors, sleep diaries confirmed that each participant had a stable sleep/wake cycle (no shift work) with adequate opportunity for sleep.

Control Recruitment

Good-sleeping controls were recruited from research advertisements placed online and in the local community. With each control participant, we confirmed that they did not meet the criteria for Insomnia Disorder (DSM-5; APA, 2013), through telephone screening and prior to the sleep study.

Exclusion Criteria

Participants were deemed ineligible for the study if they were < 18 years, pregnant or lactating, had recently used illicit psychoactive substances, had an alcohol/caffeine dependence, had recently been on medication that interfered with their sleep (within 1 month of assessment), any co-morbid psychiatric/sleep disorder other than mild-to-moderate depression, severe cognitive impairment, were overnight shift workers, had recently travelled across two time-zones in the last month, or were currently receiving treatment for an existing sleep disorder.

Participants

G*Power analysis, which was based on the effect size reported by Remington, Swettenham, Campbell and Coleman (2009) ($\eta p2 = .074$) who used a similar perceptual load manipulation and a patient/control approach, indicated that a minimum sample size of 22 participants (power at .80) would be required to detect group differences. Therefore, twenty-

three adults (Female $N = 13$, 57%) with a clinical diagnosis of Insomnia disorder and 23 good-sleeping age-, and sex-matched controls (Female $N = 13$, 57%) participated in the study (Table 1). All participants undertook the same protocol except insomnia patients were enrolled into a digital cognitive behavioural therapy for insomnia after baseline testing (SHUTi; Ritterband et al., 2009), whereas control participants received a $200 participation fee.

Procedure

On the evening prior to the attention task, all participants attended the sleep laboratory and were set-up with sensors attached for an overnight polysomnographic (PSG) sleep recording. Participants were then provided with time to adjust to the lab environment and individual bedtime and time for 'lights out' (time at which they attempted to initiate sleep) was selected from seven-ten days of proceeding sleep diary data and verified by using actigraphy (i.e. a watch-like device worn prior to laboratory testing that provide objective sleep-wake parameters). All participants were monitored overnight by a trained sleep technologist with 'lights on' occurring in line with their usual habitual wake time. Participants were then instructed to go about their normal day and to return to the laboratory in the early evening (around 6 pm), followed by the opportunity to have an evening meal. They were then set-up for overnight polysomnographic evaluation and were sampled for salivary melatonin concentrations as part of the parent study. The selective attention task was standardised to occur at two hours prior to the normal bedtime of each participant (9:38pm on average in the insomnia patients (SD = 68 minutes) and 9:43pm on average in the controls (SD = 51 minutes)) and took approximately 25 minutes to complete for both groups. Participants then completed the study protocol consisting of assessment of dim light melatonin onset (DLMO) and a 30 minute simulated drive. These results are not reported here.

Selective Attention Task

The selective attention task consisted of 108 visual search trials. On each trial participants were presented with a circle of six letters containing the target letter X or N. As seen in Figure 1, during low perceptual load trials the search set consisted of a target letter and 5 lower case 'o's (set size 1), on medium perceptual load trials the search set consisted of a target letter, 3 similar non-targets (taken from the set Z M W K V H) and 2 lower case 'o's (set size 4), while high load trials consisted of a target letter and five non-targets (set size 6). The target and non-target letters were 0.6° x 0.4° of visual angle in size, and together with the lower case 'o's (0.15° x 0.12°) were presented in white and set upon a black background. Across the task, the target letter was equally likely to be X or N, and it was equally likely to appear in any of the six letter positions in the search circle. Distractor letters could be neutral in relation to the target (L or T), congruent to the target (X if the target was X, N if the target was N), or incongruent to the target (N if the target was X, X if the target was N) engendering response competition. A single distractor letter (1° x 0.6° in size) appeared on all trials, located with equal probability to the left or right of the search circle (0.5° from the edge of the nearest letter within the search set).

At the start of each trial, a fixation point was presented at the centre of the screen for one second, followed by a 200 millisecond letter search display after which a blank screen was displayed for 1800 milliseconds. This provided 2 seconds for the participants to make a response, which they did by pressing '0' for target letter X and '2' for target letter 'N'. If the response was incorrect, or no response was detected, a visual feedback display was presented for the final 1000 milliseconds of the trial. Each trial lasted 3 seconds in total. The requirement for fast and accurate letter search responses was emphasised to participants. Participants completed 36 practice trials (12 per load condition) with no distractors present. The 108 experimental trials (36 trials per load condition) were randomly intermixed within a single

block, and across the experiment, the distractor letter was equally likely to be neutral, congruent or incongruent to the target.

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Results

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Reaction Times (RTs)

Following the procedure reported by Lavie (1995), initial ANOVAs confirmed that there was no difference in response times or error rates for neutral distractors compared to congruent distractors in either group (all $p > 0.05$ see Table 2). Therefore, in order to compare RTs when the distractor had no association with the target (baseline RTs) and when the distractor created response competition, the main analysis focused on reaction times when the distractor was either neutral (N) or incongruent (I) to the target. Table 2 shows mean RTs presented as a function of perceptual load and congruency condition (N/I).

Participants mean correct RTs were entered into a 2 x 3 x 2 mixed design ANOVA with the between subjects factor of group (insomnia, control), and within subjects factors of perceptual load (low, medium, high) and distractor condition (neutral, incongruent). ANOVA revealed a main effect of perceptual load, $F(2, 88) = 74.06$, $p < 0.001$, $\eta_p^2 = 0.65$, with RTs increasing significantly with subsequent increases in the perceptual load during each task (low load: $M = 799$ms; medium load: $M = 937$; high load: $M = 971$ms; all p's $< .01$), confirming that the perceptual load manipulation was successful. There was also a main effect of distractor condition which was qualified by a load x distractor condition interaction, $F(2, 88) = 4.19$, $p = 0.018$, $\eta_p^2 = 0.08$. The source of the interaction was revealed to be a reduction in the distractor cost (incongruent distractor RTs-neutral distractor RTs) as the level of perceptual load increased. The distractor cost was reduced between low load ($M = 61$ms) and medium load ($M = 15$ms; $t(45) = 2.38$, $p = 0.022$, d = , 95% CI [7ms-85ms]), with no difference between medium and high load ($M = 14$ms; $t < 1$ for the difference). This finding supports the predictions made

by load theory, with the response competing distractor being perceived under low load, and effectively filtered from perception at medium/high load (set sizes 4-6; see Remington et al, 2009; Lavie, 2011).

There was a significant group x distractor condition interaction ($F(1, 44) = 6.13$, $p = 0.017$, $\eta_p^2 = 0.12$; Figure 2). Follow-up analysis revealed a significantly higher distractor cost in the insomnia group (M = 51ms) across load conditions compared to the control group ($M = 8$ms; $t(44) = -2.48$, $p = 0.017$, $d = .73$, 95% CI [7ms-77ms]). There was no overall main effect of group ($F < 1$) or the three-way interaction between group, load and distractor condition ($F < 1$). There was also no load x group interaction ($F < 1$), suggesting that the effect of load on distractor processing was the same for both groups. This pattern of results suggests that while those with insomnia show greater baseline levels of distraction relative to controls, as can be seen in Figure 2, the condition does not appear to compromise the effectiveness of the selective attention mechanism.

Six controls and two insomnia patients showed a distractor cost that was in the opposite direction to the well-established effect. This could be due to misunderstanding the task instructions, or in some cases having fewer incongruent trials for analysis due to greater than average error rates. However, in a re-analysis of the data without these participants, the pattern of findings was retained with greater distraction in the insomnia group compared to the control group.

Error rates

Participants mean error rates were entered into a 2 x 3 x 2 mixed design ANOVA with the between subjects factor of Group (Insomnia, Control), and with within subjects factors of Perceptual Load (low, medium, high) and Distractor Condition (neutral, incongruent). There was a main effect of load ($F(2, 88) = 88.94$, $p < 0.001$, $\eta_p^2 = 0.67$), with error rates increasing significantly with each increase in the level of perceptual load of the task (low load $M = 17\%$; medium load $M = 29\%$; high load $M = 37\%$; p's < 0.05). This confirmed that the perceptual load in the task had been manipulated. There was also a main effect of distractor condition using the load x distractor condition interaction ($F(2, 88) = 6.32$, $p = 0.003$, $\eta_p^2 = 0.13$). The source of the interaction mirrored that of the RTs, with a greater distractor cost (incongruent distractor error rates - neutral distractor error rates) under low load ($M = 17\%$) than medium load ($M = 7\%$; $t(45) = 3.97$, $p < 0.001$, $d = .67$, 95% CI [4%-14%]), with no differences between medium and high load ($M = 11\%$; $t(45) = -1.32$, $p = 0.19$, $d = .28$, 95% CI [-9%-1%] for the difference). This finding supports the predictions made by load theory in the same way as described for the same effect on RTs. The main effect of group was not significant, and neither were the two and three-way interactions including group as a factor (p's > 0.09), there were therefore no significant differences in error rates between the groups.

Symptom Scores and Distractibility

We examined the extent to which ISI and PSQI scores predicted the level of distractor cost (I-N low load RTs) in the insomnia group. There was a significant positive correlation between increased ISI scores and increased distractor cost, $r(21) = 0.47$, $p = 0.033$, 95% CI [.04-.74]; whereas PSQI scores and distractibility were not significant $r(17) = -0.26$, $p = 0.319$, 95% CI [-.61-.19] (For the correlation dataset, two participants who did not exhibit a distractor

cost under low load were removed from the analysis. In addition, ISI/PSQI scores were not available for 1 and 5 participants respectively).

Discussion

Patients with insomnia describe diminished ability to focus attention and ignore task irrelevant distraction (i.e. the ability maintain effective concentration on a task). In this study, we confirmed these subjective reports using an objective measure which showed that individuals with clinically diagnosed insomnia were significantly more distracted than control participants when there was sufficient perceptual capacity for distractors to be perceived. However, increasing the level of perceptual load in the search task was equally as effective in the extent to which it reduced distractor processing in both groups. These findings suggest that while those with insomnia may show greater levels of baseline distraction (i.e. under low load) their selective attention mechanism however, remains intact.

In addition to assessing selective attention and distraction in Insomnia, we also assessed a third key question as to whether self-report insomnia symptom measures could predict the level of distractibility in the attention task. We used the Insomnia Severity Index (ISI) and the Pittsburgh Sleep Quality Index (PSQI), two well established clinical measures of insomnia symptoms (ISI) and impaired overall sleep quality (PSQI), and we found that while ISI scores positive correlated with participant distractor cost, PSQI scores did not. These findings suggest increased insomnia severity specifically and not overall poor quality sleep may be associated with increased distractibility in those with insomnia, and by extension, the magnitude of general daytime impairments in cognitive functioning. However, the distractor cost-ISI score correlation must be treated with caution as the sample size here is small, and the correlation is only moderate in size and marginal in significance.

In real-world contexts, things that distract us often tend to be entirely task irrelevant (e.g. focusing on writing a report while being distracted by a telephone ringing in an adjacent office). Therefore, in order to ensure that the heightened distractibility reported in the insomnia group in this study is likely to mirror real world distraction, a task should seek to replicate our findings using entirely task irrelevant distractors (see Forster & Lavie, 2007; Forster et al., 2014). Our paradigm used distractors which were related to the primary task (i.e. distractor letters when the target and non-targets were also letters) and future work should now evaluate insomnia specific distractors relating to sleep. In addition, to provide convergent data, the assessment of detection rates of irrelevant auditory (Inattentional Deafness tasks, see Raveh & Lavie, 2015) and tactile (Inattentional Numbness tasks, see Murphy & Dalton, 2016) stimuli under load could also provide evidence for our view that in those with insomnia, a greater level of processing is attributed to irrelevant stimuli even those out with the visual domain.

Interestingly, our findings mirror those reported in a study of adults with Attention Deficit Hyperactivity Disorder (ADHD) by Forster, Robertson, Jennings, Asherson and Lavie (2014). Forster et al. (2014) used the experimental approach that we have adapted for use in the present study, and asked participants with ADHD to ignore entirely task irrelevant distractors (i.e. colourful cartoon characters) while completing a letter search task which varied in the level of perceptual load. In line with the findings from the present study, Forster et al. (2014) reported that the task was sensitive enough to detect greater distraction in those with ADHD, and that ADHD symptom severity was associated with patient distractor cost. These findings, along with our own, suggest that the perceptual load framework is a good approach for assessing distractibility in clinical groups such as ADHD and insomnia (see Remington et al., 2009 for use in Autism).

The findings reported above were generated from an exploratory study which sought to assess whether the perceptual load framework would provide a good approach to studying

selective attention and distraction in a clinically diagnosed sample of patients with chronic insomnia. The results are promising, and suggest that our distractor task could be a good measure of daytime impairments in patients with insomnia, they suggest that the focus on distraction in insomnia should be on frontal control deficits rather than the selective attention mechanism, and that the ISI, rather than the PSQI, would appear to provide a valid measure of the magnitude of daytime distractibility. However, future research should seek to replicate these findings with a larger and more clinically diverse samples, a larger number of experimental trials, and entirely task irrelevant distractors. In addition, while we only assess distractibility at one point during the day, future studies assessing distractor cost in those with insomnia throughout the daytime period. The circadian rhythm was not assessed here and may be a contributing factor. If differences in distractor cost in those with insomnia arose across the day, work tasks and periods of driving could be restricted to the times of day at which they are least likely to be distracted.

Despite the limitations noted above, our findings suggest that the use of the perceptual load theory framework to assess daytime attentional impairments in insomnia has the potential to enhance our understanding of the cognitive processes that underlie the condition, as well as to provide effective interventions strategies which target insomnia related deficiencies in frontal control processes.

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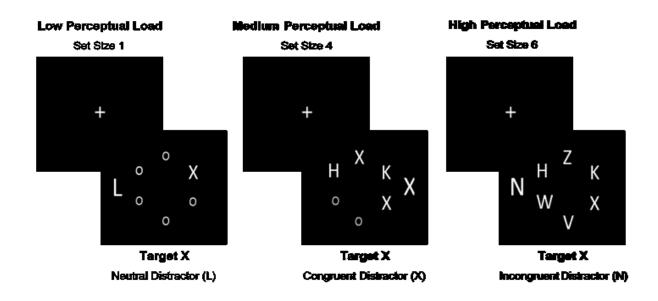
Table 1 Sample Characteristics

Mean Age, ISI and PSQI questionnaire scores. Total Sleep Time, Mean Sleep Onset Latency and Mean Wake-Time After Sleep Onset as recorded by overnight polysomnographic assessment.[1]

	Insomnia Group (N = 23)			Control Group (N = 23)			Diff.
Measure	Mean	SD	Range	Mean	SD	Range	*p*
Age (yrs)	32	8	18-48	30	9	18-50	ns.
Insomnia Severity Index (ISI)	19	4	12-27	3	3	0-9	< .001
Pittsburgh Sleep Quality Index (PSQ	13	3	9-18	4	2	1-7	< .001
Total Sleep Time (mins)	362	82	201-529	338	80	100-464	ns.
Sleep Onset Latency (mins)	18	21	0-99	43	41	5-149	< .015
Wake-Time After Sleep Onset (mins)	73	58	0-215	31	22	6-86	< .001

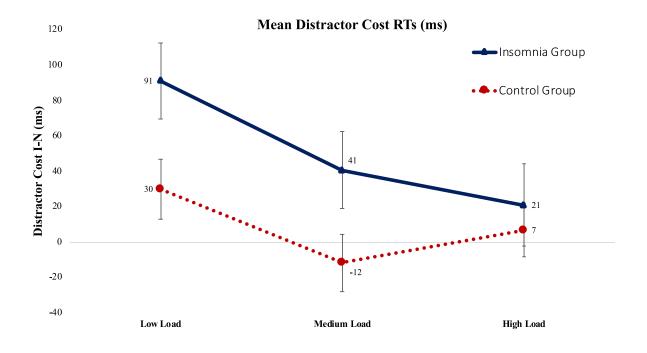[1] Note: We report no significant difference in Total Sleep Time between patients and controls. This could be due to the phenomenon known as the first-night effect (Coble et al., 1974) in which good sleepers experience a poorer than usual night's sleep during the first night in the sleep lab, and, paradoxically, patients with insomnia can sometimes show improved sleep during their first sleep in a lab environment (Hauri & Olmstead, 1989).

Table 2 Mean reaction times (milliseconds) for each group, level of perceptual load and neutral/incongruent distractor condition.

	Insomnia Group				Control Group			
	Neutral Distractor		Incongruent Distractor		Neutral Distractor		Incongruent Distractor	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Low Load	765	187	856	180	773	130	803	151
Medium Load	935	160	975	161	924	139	912	134
High Load	969	169	990	175	960	147	966	170

Figure 1 Example trials from the perceptual load task showing low, medium and high load trials and distractor position (left, right) and target-distractor congruency (neutral, congruent, incongruent).

Figure 2 Mean distractor cost (incongruent distractor RTs– neutral distractor RTs) between insomnia and control across the low, medium and high perceptual loads. Error bars indicated one standard error of the mean.