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Sleeping with the enemy: Clock monitoring in the maintenance of insomnia

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Abstract

Two experiments that aimed to investigate the association between clock monitoring, pre-sleep worry and sleep are presented. In Experiment 1, 30 good and 30 poor sleepers were instructed either to monitor or not to monitor a clock as they were trying to get to sleep. Worry was indexed by self-rating. Sleep was measured by self-report and actigraphy. Compared to non-monitors, clock-monitors reported more pre-sleep worry and they experienced longer sleep onset latency (SOL). These findings held true for both good and poor sleepers. In Experiment 2, following one night of baseline measurement, 38 individuals diagnosed with primary insomnia were instructed to monitor either a clock or a digit display unit (a control monitoring task) as they were trying to get to sleep. The clock-monitoring task was rated to be more worry provoking and sleep interfering than the display unit-monitoring task. Whilst display unit-monitors experienced less pre-sleep worry, the clock-monitors experienced more pre-sleep worry and reported a longer SOL on the experimental night, relative to baseline. Further, compared to the display unit-monitors, the clock-monitors overestimated their SOL more on the experimental night. Together, these findings suggest that clock monitoring may trigger

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pre-sleep worry and serve to maintain insomnia by fuelling pre-sleep worry and exacerbating misperception of sleep.

Keywords: Misperception; Attention; Monitoring; Worry; Insomnia; Sleep

1. Introduction

There is ample evidence that individuals with insomnia attribute their difficulty with sleep to excessive pre-sleep worry. People with insomnia are 10 times more likely to cite cognitive arousal as central to their sleep disturbance compared to somatic arousal (Lichstein & Rosenthal, 1980). Further, on the Sleep Disturbance Questionnaire, the items implicating cognition as the major cause of the sleep disturbance (e.g., 'My minds keeps turning things over', 'I am unable to empty my mind') are the most highly rated (Espie, Brooks, & Lindsay, 1989; Harvey, 2000). Whilst previous research has carefully documented the content of the pre-sleep worry (Harvey, 2000; Watts, Coyle, & East, 1994; Wicklow & Espie, 2000), a key question that remains unanswered is what triggers and maintains this excessive pre-sleep worry.

Attentional bias toward threat-related material has been implicated as a trigger to threat perception and excessive worry across a range of psychological disorders (Beck, Emery, & Greenberg, 1985; Clark, 1999; Ehlers & Breuer, 1992). In the context of insomnia, a recent cognitive model of insomnia (Harvey, 2002) and clinical observation (Bearpark, 1994; Hauri, 1991; Morin, 1993) have implicated an attentional bias in the form of 'clock watching' during the pre-sleep period to be a trigger to excessive pre-sleep worry. Specifically, it has been proposed that periodic monitoring of the clock, during the pre-sleep period, to see how long it is taking to fall asleep will fuel worry about not getting to sleep. Escalating worry, in turn, is suggested to contribute to difficulty achieving sleep onset (Harvey, 2002). Whilst such a suggestion has intuitive appeal, the hypothesised links between clock monitoring, pre-sleep worry and difficulty achieving sleep onset have not been tested empirically. Hence, the present paper presents two interlinked experiments that sought to investigate the impact of clock monitoring.

2. Experiment 1

The aim of Experiment 1 was to determine whether monitoring the clock (1) triggers pre-sleep worry and (2) contributes to difficulty falling asleep. On the experimental night 'good sleepers' and 'poor sleepers' were instructed either to monitor the clock or to not monitor the clock whilst trying to get to sleep. Three predictions were tested. First, given that attentional bias toward threat-related material has been repeatedly implicated as a trigger of worry (e.g., Beck et al., 1985), it was predicted that participants instructed to monitor the clock would, relative to participants instructed not to monitor the clock, report more pre-sleep worry. Second, on the basis that pre-sleep worry is one mechanism by which clock monitoring may be detrimental to optimal sleep onset (Harvey, 2002), it was expected that participants instructed to monitor the clock would take longer to get to sleep compared to participants instructed not to monitor the clock. Third, based on previous findings that a cognitive manipulation during the pre-sleep period can induce a 'state' of insomnia in good sleepers (e.g., Ansfield, Wegner, & Bowser, 1996), we reasoned that hypotheses 1 and 2 would hold for both the good sleeper and poor sleeper groups.

3. Method

3.1. Participants

A total of 68 volunteers were recruited; 28 were residents from a single housing estate and 40 were graduate students or staff from the University of Oxford, UK. Criteria for entering the 'poor sleeper' group were (1) a score of more than 5 on the Pittsburg Sleep Quality Index[1] (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), (2) presence of a disturbance relating to sleep onset (score of 2 or 3 on question 5a of the PSQI), and (3) evidence that the sleep disturbance significantly interfered with occupational, social or some other important areas of functioning (score of 2 or 3 on question 8 of the PSQI). Criteria for entering the 'good sleeper' group was the absence of a disturbance relating to sleep onset and maintenance as determined by the PSQI. Exclusion criteria included indicators of (1) the presence of a sleep disorder that might account for the insomnia, (2) non-compliance with instructions to monitor/not monitor the clock, (3) use of alcohol or sleep medication on the night of the experiment, and (4) the occurrence of events on the night of the experiment that interfered with sleep. Eight participants were excluded; four failed to meet criteria for inclusion in one of both experimental groups and four failed to comply with instructions to monitor/not monitor the clock. The final sample comprised 60 participants; 30 good sleepers and 30 poor sleepers who were randomly assigned to either a clock monitoring or a no clock monitoring condition.

3.2. Apparatus

3.2.1. Sleep diary

To index the impact of clock monitoring, the sleep diary asked the participants to (1) record the time it took them to fall asleep (sleep onset latency; SOL) on the night of the experiment, (2) rate their SOL on the night of the experiment compared with the average SOL over the last month (response scale: -5 much more quickly to $+5$ much longer; this rating will be known as the 'comparison rating'), and to (3) rate the extent to which worrying about how long it was taking them to fall asleep interfered with getting to sleep (response scale: 0 not at all to 10 very much; this rating will be known as the 'worry rating'). As a check of task compliance, the participants were asked to indicate whether they had monitored the clock during the pre-sleep period (response choice: Yes, No). Finally, the sleep diary asked the participants to record their alcohol consumption and intake of sleep medication on the night of the experiment, naps taken the day prior to the

[1]A global score (sum of the seven component scores) of above five identifies a clinical sleep disorder with specificity and sensitivity as high as 90%.

experiment, and unusual events that occurred during the night of the experiment (e.g., late night phone call, fire alarm, illness).

3.2.2. Actigraphy

A Mini Motionlogger Actigraph Basic (supplied by AM, Inc.) was employed to provide an objective estimate of sleep. Cased within the actigraph is a miniaturised piezoelectric sensor programmed to detect and store physical motion data in Zero-Crossing Mode at 60-s intervals. Stored data was downloaded for analysis using compatible software (Action W) and conversion of data into sleep parameters was completed using the Cole–Kripke algorithm (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992), with Webster's rescoring rules (Webster, Kripke, Messin, Mullaney, & Wyborney, 1982). The validity of actigraphy has been extensively investigated. The correlation between actigraphy- and polysomnography-defined sleep estimates ranges from 0.88 to 0.97 in adult good sleepers and 0.79–0.90 in patients with insomnia (e.g., Cole et al., 1992; Jean-Louis et al., 1997a; Sadeh, Alster, Urbach, & Lavie, 1989). The accuracy[2] of actigraphy in identifying sleep and wakefulness ranges from 82% in normal adults (Blood, Sack, Percy, & Pen, 1997) and 76–77% in patients with insomnia (Kushida et al., 2001).

3.3. Design

The experimental manipulation involved asking both good sleepers and poor sleepers to either monitor the clock (good sleeper/monitors: $n = 15$; poor sleeper/monitors: $n = 15$) or not to monitor the clock (good sleeper/non-monitors: $n = 15$; poor sleeper/non-monitors: $n = 15$) as they were trying to get to sleep. On this night, the participants were asked to wear an actigraph and to complete a sleep diary immediately upon waking.

3.4. Procedure

After obtaining informed consent, the PSQI and the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) were administered. A semi-structured interview was then conducted to screen for the presence of a sleep disorder that might account for the insomnia. The interview included questions to screen for sleep apnea, restless legs syndrome, bruxism and circadian rhythm dysregulation. No participants endorsed any screening question. The participants were then given task instructions according to the experimental condition to which they were assigned. The monitors were asked to 'use the clock to track exactly how long it takes [them] to fall asleep', whereas the non-monitors were asked '[not] to look at the clock at all'. All participants were asked to wear the actigraph on their non-dominant wrist at least 2 h prior to bedtime and to wear it until they got out of bed the next morning. In addition, they were asked to refrain from using sleep medication or consuming alcohol on the night of the experiment. Before leaving the session participants were given two envelopes. The first envelope, labelled 'Bedtime Notes', contained a written reminder of the task to be completed. The participants were told to open this envelope and read the contents just prior to switching

[2]Accuracy = proportion of polysomnography epochs (sleep and wake) correctly identified by actigraphy.

off the light. The second envelope, labelled 'Morning Notes', contained the sleep diary. The participants were asked to open and complete the sleep diary as soon as practical upon waking.

4. Results

Unless otherwise stated, the following analyses are based on a series of 2 (sleeper: poor sleeper vs. good sleeper) by 2 (instruction: monitor vs. do not monitor the clock) ANOVAs.

4.1. Participant characteristics

As evident in Table 1, the four groups did not differ on sex-composition (analysed with χ^2) or age. A significant sleeper main effect was found for global PSQI score, $F(1, 56) = 160.1$, $p<0.001$, and BDI, $F(1, 56) = 19.6$, $p<0.001$, such that poor sleepers had a higher score on the PSQI and BDI (indicating worse symptoms) compared to good sleepers. There was a significant sleeper main effect for SOL over the last month, $F(1, 56) = 54.0$, $p<0.001$ (data obtained from question 2 of the PSQI). That is, over the past month, poor sleepers took longer to fall asleep compared to good sleepers. There was no Instruction main effect or interaction for any participant characteristic variable.

Table 1
Participant characteristics and other dependent variables for Experiment 1

	Good sleeper		Poor sleeper		Main effects for major variables			
	Monitor	Non-monitor	Monitor	Non-monitor	Sleeper effect		Instruction effect	
					F (1, 56)	p	F (1, 56)	p
Participant characteristics								
Sex								
Female	8	7	6	9				
Male	7	8	9	6				
Age (years)	34.9 (7.0)	37.2 (8.1)	34.8 (10.6)	32.0 (9.8)				
PSQI	2.5 (1.0)	2.5 (1.4)	9.1 (2.5)	8.3 (2.2)	160.1	0.001	0.5	0.50
BDI	3.3 (2.4)	4.7 (3.9)	8.3 (4.3)	9.7 (6.0)	19.6	0.001	1.6	0.21
Typical SOL (mins)	9.3 (7.1)	5.4 (4.3)	52.9 (30.6)	51.3 (34.9)	54.0	0.001	0.2	0.66
Sleep diary								
Worry rating	2.9 (3.0)	1.3 (1.8)	4.9 (3.9)	1.4 (1.7)	2.1	0.16	12.0	0.01
SOL (mins)	33.2 (34.0)	8.1 (5.8)	60.3 (37.7)	35.3 (27.0)	13.3	0.01	11.3	0.01
Comparison rating	2.8 (1.7)	0.6 (2.3)	1.0 (1.6)	−1.1 (1.8)	13.4	0.01	20.1	0.001
Actigraphy								
SOL (mins)	10.0 (10.4)	7.3 (4.4)	24.2 (22.1)	12.8 (6.1)	8.9	0.01	4.6	0.05

Note: Except for sex where frequency is reported, mean values are presented with standard deviations in parentheses. PSQI = Pittsburgh Sleep Quality Index. BDI = Beck Depression Inventory. Typical SOL = typical sleep onset latency over the past month. Worry rating = rating of the extent to which worrying about how long it was taking to fall asleep interfered with getting to sleep (on a scale from 0 'not at all' to 10 'very much'). Comparison rating = rating of how long it took to fall asleep on the night of the experiment compared to the average over the last month (on a scale from –5 'much more quickly' to +5 'much longer').

4.2. The effect of clock monitoring

4.2.1. Sleep diary data

Table 1 also presents the mean scores for variables indexed by the sleep diary. For the 'worry rating', there was a significant main effect for Instruction, $F(1, 56) = 12.0$, $p<0.01$, such that the clock-monitors rated that they were more likely to be kept awake by worrying about how long it was taking to fall asleep compared to the non-monitors. There was no sleeper main effect or interaction. For estimated SOL, there was a significant main effect for sleeper, $F(1, 56) = 13.3$, $p<0.01$, and instruction, $F(1, 56) = 11.3$, $p<0.01$, such that the poor sleepers estimated their SOL to be longer compared to the good sleepers and the clock-monitors estimated their SOL to be longer compared to the non-monitors. There was no interaction. For the 'comparison rating', there was a significant main effect for sleeper, $F(1, 56) = 13.4$, $p<0.01$, and instruction, $F(1, 56) = 20.1$, $p<0.001$, such that the good sleepers reported that they took longer to fall asleep on the night of the experiment compared to the length of time it took them to fall asleep over the last month. Their ratings were significantly higher (i.e., took 'much longer' to fall asleep) compared to the ratings made by the poor sleeper group. The clock-monitors reported that they took longer to fall asleep on the night of the experiment compared to the length of time it took them to fall asleep over the last month. Their ratings were significantly higher (i.e., took 'much longer' to fall asleep) compared to the non-monitors. There was no interaction.

4.2.2. Actigraphy data

Table 1 also presents the mean scores for SOL estimated by the actigraph. There was a significant main effect for sleeper, $F(1, 56) = 8.9$, $p<0.01$, and instruction, $F(1, 56) = 4.6$, $p<0.05$, such that the poor sleepers took longer to get to sleep compared to the good sleepers and the clock-monitors took longer to get to sleep compared to the non-monitors. There was no interaction.

4.2.3. Post-hoc analysis

Analysis of the subjective versus objective sleep data revealed an interesting result. The analysis was based on a discrepancy score that was calculated by subtracting SOL as recorded by the actigraph (objective SOL) from SOL recorded in the sleep diary (subjective SOL). The sleeper main effect was marginally significant, $F(1, 56) = 3.9$, $p = 0.053$. That is, poor sleepers showed a tendency to overestimate their SOL significantly more compared to good sleepers. There was a significant main effect for instruction, $F(1, 56) = 6.3$, $p<0.05$. That is, clock-monitors overestimated their SOL significantly more compared to non-monitors. There was no interaction.

5. Discussion

Consistent with the first hypothesis, clock-monitors had a higher 'worry rating' than non-monitors. That is, clock-monitors worried more about how long it was taking them to fall asleep and they felt that this interfered with them getting to sleep. This finding lends support to the proposal that one trigger to pre-sleep worry is clock monitoring (Harvey, 2002). Interestingly, the 'worry rating' for poor sleeper/non-monitors was lower ($M = 1.4$, $SD = 1.7$) than expected from a population known to be characterised by pre-sleep worry. This finding may be attributable to the analogue nature of the sample (self-reported poor sleepers, not individuals diagnosed with insomnia). Alternatively, perhaps banning clock monitoring for this group reduced their worry. In line with the second hypothesis, clock-monitors experienced longer SOL, as indexed by the sleep diary and actigraphy, compared to non-monitors. Further, as indicated by the 'comparison rating', clock-monitors rated that they took longer than usual to fall asleep on the night of the experiment, relative to non-monitors. These findings are consistent with clinical observations as to the sleep-interfering effect of clock monitoring (Bearpark, 1994; Hauri, 1991; Morin, 1993). They are also consistent with the proposal that monitoring the clock may be involved in the maintenance of insomnia (Harvey, 2002). The third hypothesis was that the detrimental effects of clock monitoring would be equally evident across groups. In support, both poor and good sleepers monitors were more likely to report pre-sleep worry and were more likely to experience longer SOL compared to non-monitors (i.e., there were no interaction effects). In other words, clock monitoring appears to induce a 'state' of insomnia in individuals who do not normally have difficulty falling asleep. This finding is consistent with previous research with good sleepers (e.g., Ansfield et al., 1996).

Counterintuitively, a comparison of subjective SOL (from the sleep diary) and objective SOL (from actigraphy) revealed that instructions to monitor the clock led participants to overestimate SOL relative to instructions to not monitor the clock. We offer two tentative explanations for this finding. The first is based on the finding that time seems longer as the number of units of information processed per unit of time is increased (Thomas & Cantor, 1976). As the clock-monitors had to process more information as a function of the clock-monitoring task and as they also worried more about how long it was taking them to fall asleep, this group is likely to have processed more information units, which may have constituted a psychological basis for time overestimation. Based on these ideas, it has recently been suggested that monitoring for sleep-related threat, including monitoring the clock, has two adverse outcomes; increasing worry and increasing misperception of sleep (Harvey, 2002). Second, detailed analysis of the actigraphic data from the present study revealed that in the first 60 min after sleep onset clock-monitors had more awakenings ($M = 1.9$, $SD = 1.2$) than non-monitors ($M = 0.6$, $SD = 0.8$), $F(1, 56) = 19.2$, $p < 0.001$ (there was no sleeper main effect or interaction). It is possible that the increased worry associated with monitoring made it more difficult for participants to move into the deeper stages of sleep. Also, it is possible that repeated awakenings may have been perceived as continuous wakefulness (Knab & Engel, 1988).

The results of this experiment must be considered in the light of three limitations. First, although those in the poor sleeper group reported having a sleep difficulty that significantly interfered with their daily functioning and scored an average of 8.7 on the PSQI, the diagnostic status of this group was not confirmed. As such, the generalisability of the findings of the present study to an insomnia sample is unknown. Also, the recruiting procedure did not include the assessment of comorbid psychological and medical disorders that may account for the insomnia. Second, whilst the no monitoring task could be performed with minimal effort, the clock-monitoring task required participants to keep their eyes open and to process information. Further investigation is required to separate the unique impact of clock monitoring from the effect of the mere act of monitoring. Third, this study was conducted over one night, which necessitated a comparison between the sleep obtained on the experimental night with a typical night in the past month. Smith, Smith, Nowakowski, and Perlis (2003) have drawn attention to potential biases associated with the latter measure, including averaging and identifying a 'typical night'. Experiment 2 aimed to address these limitations.

6. Experiment 2

The aim of Experiment 2 was to further examine the association between clock monitoring, pre-sleep worry and sleep, correcting for the limitations of Experiment 1. Major changes made to the experimental design are summarised as follows: first, with the goal of increasing the generalisability of the findings to chronic insomnia, a sample who met strict diagnostic criteria for primary insomnia was recruited instead of the self-reported poor sleepers used in Experiment 1. Structured clinical interviews were employed to screen out participants who did not meet the criteria for insomnia or who had insomnia secondary to another sleep disorder, mental disorder, medical condition or the effect of a substance. Second, to provide baseline data for within-subjects comparison, the experimental period was lengthened from one to three nights (one adaptation night, one baseline night, one experimental night). Third, to isolate the effect of clock monitoring, a digit display unit-monitoring task (a control task) was designed to control for confounding variables introduced by the mere act of monitoring (e.g., eyes being open, continuous information processing, etc.). Three predictions were tested. First, it was hypothesised that participants instructed to monitor the clock would report more pre-sleep worry than participants instructed to monitor a digit display unit on the experimental night. Second, it was predicted that clock-monitors would take longer to get to sleep than display unit-monitors. Third, based on the results of Experiment 1, we also hypothesised that clock-monitors would overestimate their SOL more than display unit-monitors.

7. Method

7.1. Participants

Participants were recruited from two local universities in Oxford, UK. A total of 51 participants responded to an advertisement asking for volunteers for sleep research and attended a 90-min screening session, during which two structured diagnostic interviews were administered: the Interview for the Diagnosis of Insomnia (IDI) and the Structured Clinical Interview for DSM-IV (SCID; Spitzer, Williams, Gibbon, & First, 1996). In the absence of a psychometrically validated alternative, the IDI is a structured clinical interview consisting of 5 sections carefully designed to assess the presence of each of the DSM-IV criteria for primary insomnia (American Psychiatric Association, 1994). To be included in the present study, participants needed to have met strict DSM-IV criteria. Additionally, participants' sleep disturbance had to have been present at least 3 nights a week for at least 1 month (Morin, 1993; World Health Organization, 1992). Since the aim was to examine the association between clock monitoring and sleep onset, participants were only included if they reported difficulty with sleep onset and sleep maintenance. Participants were excluded if they did not meet criteria for insomnia ($n = 4$), had sleep-onset or sleep-maintenance problems for only 1 or 2 nights per week ($n = 1$), had a comorbid sleep disorder ($n = 1$), did not comply with experimental instructions ($n = 4$), used alcohol and sleep medication on the experimental night ($n = 1$), or if events occurred that might have interfered with sleep on the experimental night ($n = 2$). Thus, the final sample comprised 38 patients with primary insomnia, who were randomly assigned to one of two groups: the Clock-Monitoring Group ($n = 19$) or the Display Unit-Monitoring Group ($n = 19$).

7.2. Apparatus

7.2.1. Sleep diary

Along with wearing an actigraph (as described in Experiment 1), the participants were asked to estimate their SOL in a sleep diary. Four questions were asked as an index of sleep-related worry [e.g., 'To what extent, if at all, did worrying about how long it was taking you to fall asleep interfere with you getting to sleep last night?' (response scale: 0 not at all to 10 very much)]. Given that these four worry questions had adequate internal consistency (Cronbach's $\alpha = 0.89$; item-total correlation ranged from 0.83 to 0.92; principal component analysis extracted one underlying factor accounting for 77.2% of the total variance), their ratings were summed to generate a 'pre-sleep worry score', with higher scores indicating more sleep-related worries during the pre-sleep period. Finally, the participants were asked to record their alcohol consumption, use of sleep medication, and any unusual events that interfered with sleep.

7.2.2. Digital clock

An ordinary digital clock was employed (model number 28005, supplied by Morphy Richards). It had a 12-h light-emitting diode display showing the time in hours and minutes. The (red) LED display made it possible to check the time even after the light was switched off.

7.2.3. Digit display unit

Although the digit display unit had an appearance identical to the digital clock in terms of colour and size of digits, it was programmed to display only random digits. Beginning with four randomly selected digits, one of the four digits changed randomly as each minute elapsed.

7.3. Design

The participants were asked to wear an actigraph for three consecutive nights and to complete a sleep diary for three consecutive mornings. Although 'first-night effect' associated with actigraphy has been reported to be inconspicuous in normal sleepers (Jean-Louis et al., 1997b), the effect of actigraphy among an insomnia sample has not been determined. Based on several reports the authors have received from insomnia patients describing a 'first night effect' to be associated with actigraphy, the first night in this experiment was an adaptation night and the data not used in the analyses. The second night was included to obtain baseline sleep data. The experimental manipulation took place on the third night: it involved the participants either monitoring a real digital clock (Clock-Monitoring Group) or monitoring a digit display unit (Display Unit-Monitoring Group) as they were trying to get to sleep.

7.4. Procedure

After obtaining informed consent, the IDI and the SCID were administered. The participants then completed the PSQI, Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988), BDI and the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990) to index their sleep quality, anxiety, depression and tendency to worry, respectively. Over a period of three consecutive nights, participants were asked to wear an actigraph (as per the instructions given in Experiment 1) and to complete a sleep diary immediately on waking. After doing this for two nights, the participants returned to the laboratory for a second session, during which the monitoring task to be completed on the third night was explained. All participants were told to remove their own alarm clock(s) from their bedrooms and to set up either the digital clock (Clock-Monitoring Group) or the digit display unit (Display Unit-Monitoring Group) provided by the experimenter. They were asked to place the clock/digit display unit so that it was in clear view and so that the participants could read the time/digits easily. Both groups were then given an envelope labelled 'Bedtime Notes'. For the Clock-Monitoring Group, this envelope contained written instructions reminding them to use the digital clock to 'estimate how long it takes [them] to fall asleep'. For the Display Unit-Monitoring Group, this envelope contained written instructions asking them to 'estimate how often two identical digits are displayed as [they were] trying to fall asleep'. Both groups were also given a second envelope labelled 'Morning Notes' that contained the sleep diary to be completed immediately on waking.

In the third session, a 10-question post-experiment interview was conducted. The participants were asked to indicate (1) whether they had complied with the experimental manipulation by either monitoring the clock or the display unit as they were trying to get to sleep (response choice: Yes, No; Those who answered 'No' to this question were excluded from the final analysis), (2) the frequency of monitoring (response scale: 0 hardly at all to 10 a lot), (3) the task difficulty (response scale: -5 cannot be easier to $+5$ cannot be more difficult) and (4) the task expectation (response scale: -5 will hinder falling asleep to $+5$ will help falling asleep). Finally, there were six questions asking the participants to rate the impact of the monitoring tasks (see Table 3, 1st column, for a list of the questions). At the end of the interview, the participants were debriefed and paid an honorarium.

8. Results

8.1. Participants characteristics

As evident in Table 2, the two groups did not differ on sex-composition (analysed with χ^2), age, insomnia duration, PSQI, BAI, BDI, PSWQ, and typical SOL over the past month (analysed with independent samples *t*-tests). Based on the SCID, one participant (2.6%) also met criteria for a current diagnosis of specific phobia.

8.2. Manipulation checks

As indicated previously, four participants did not monitor either the clock or the digit display unit as instructed and were thus excluded from the analyses. Independent samples *t*-tests indicated that the two groups did not differ in their ratings of monitoring frequency (Clock-Monitoring Group: $M = 5.2$, $SD = 2.3$; Display Unit-Monitoring Group: $M = 6.6$, $SD = 2.2$, *ns*), task difficulty (Clock-Monitoring Group: $M = -1.0$, $SD = 2.9$; Display Unit-Monitoring Group: $M = -1.4$, $SD = 2.9$, *ns*) and task expectation (Clock-Monitoring Group: $M = -1.7$, $SD = 1.3$; Display Unit-Monitoring Group: $M = -2.0$, $SD = 2.0$, *ns*).

Table 2
Participant characteristics for Experiment 2

	Clock-Monitoring Group	Display Unit-Monitoring Group	
Sex			χ^2 (1, $n = 38$)
Female	12	15	
Male	7	4	1.15
			t (36)
Age	23.6 (5.7)	24.1 (8.5)	−0.22
Insomnia duration	5.3 (4.2)	6.5 (10.0)	−0.49
PSQI	8.8 (2.1)	9.9 (3.5)	−1.14
BAI	6.3 (3.5)	8.7 (6.5)	−1.43
BDI	10.5 (6.8)	11.1 (8.3)	−0.24
PSWQ	51.1 (11.5)	51.7 (13.2)	0.14
Typical SOL	43.4 (16.2)	45.9 (27.5)	−0.34

Note: Except for sex where frequency is reported, mean values are presented with standard deviations in parentheses. Age and Insomnia duration are reported in years. PSQI = Pittsburgh Sleep Quality Index. BAI = Beck Anxiety Inventory. BDI = Beck Depression Inventory. PSWQ = Penn State Worry Questionnaire. Typical SOL = typical sleep onset latency over the past month (measured in minutes).

8.3. The impact of the monitoring tasks

The mean ratings for items assessing the impact of the monitoring tasks are displayed in Table 3. Overall, the clock-monitoring task was rated to be more worry provoking and sleep interfering than the display unit-monitoring task. Independent samples *t*-tests detected significant differences for four out of the six items.

Unless otherwise stated, the following analyses involved a series of two-way repeated measures ANOVAs with Group (Clock-Monitoring Group vs. Display Unit-Monitoring Group) as the between-subjects variable and night (baseline vs. experimental night) as the within-subjects variable. Independent samples *t*-tests were conducted to explore significant interactions. In addition, effect sizes (*ES*) and observed powers (*power*) were calculated for significant between- and within-groups differences detected.

8.4. Sleep diary data

8.4.1. Pre-sleep worry

There was no significant main effect for group or night. There was a significant group by night interaction, F (1, 36) = 13.1, $p < 0.001$. Follow-up tests indicated that the Clock-Monitoring Group experienced more pre-sleep worry on the experimental night ($M = 13$, SD = 11) as compared to baseline ($M = 6.7$, SD = 7.7; $p < 0.05$) ($ES = 0.66$, $power = 0.87$). This increase in pre-sleep worry was in contrast to the decrease in pre-sleep worry noted in the Display Uni-Monitoring Group (baseline: $M = 12.3$, SD = 9.9; experimental night: $M = 7.7$, SD = 8.5; $p < 0.05$) ($ES = -0.49$, $power = 0.67$).

8.4.2. Subjective SOL

There was no significant main effect for group or night. There was a significant group by night interaction, F (1, 36) = 5.4, $p < 0.05$. Follow-up tests indicated that the Clock-Monitoring Group estimated their SOL to be longer on the experimental night ($M = 36.6$,

Table 3
Mean ratings for the impact of the monitoring tasks

'To what extent, if at all, did the task…	Clock-Monitoring Group	Display Unit-Monitoring Group	t (36)	p
… make you become more aware of the passing of the time?'	6.9 (2.8)	4.2 (3.3)	2.76	0.009**
… make it difficult to fall asleep?'	4.6 (2.6)	2.4 (1.8)	3.02	0.005**
… make you feel more frustrated about not being able to fall asleep quickly?'	5.1 (3.1)	1.6 (2.2)	3.96	0.000***
… make you worry that you are not going to get 'enough' sleep?'	4.7 (3.8)	1.9 (2.0)	2.91	0.007**
… make you worry about the effect of not getting to sleep on your performance the following day?'	3.8 (3.4)	2.0 (2.4)	1.95	0.06
… make you worry about losing control over your sleep?'	2.0 (2.6)	1.2 (2.1)	1.10	1.10

Note: Standard deviations appear in parentheses. Response scale for all six questions: 0 not at all to 10 very much so. $^{**}p<0.01$, $^{***}p<0.001$.

SD = 18.5) as compared to baseline ($M = 27.4$, SD = 13.4) ($p<0.05$; $ES = 0.57$, $power = 0.77$). In contrast, the Display Unit-Monitoring Group estimated their SOL to be shorter on the experimental night ($M = 23.9$, SD = 14.8) as compared to baseline ($M = 32.1$, SD = 25.0), although this difference did not reach statistical significance. Further, on the experimental night, the subjective SOL estimate provided by the Clock-Monitoring Group was longer than that given by the Display Unit-Monitoring Group ($p<0.05$; $ES = 0.75$, $power = 0.74$). Similar between-groups difference was not noted at baseline.

8.5. Actigraphy data

8.5.1. Objective SOL

There was no significant main effect for Group or Night. There was no interaction. At baseline, the mean objective SOLs were 10.9 min (SD = 9.7) for the Clock-Monitoring Group and 11.2 min (SD = 7.1) for the Display Unit-Monitoring Group. On the experimental night, the mean objective SOLs were 12.3 min (SD = 9.5) for the Clock-Monitoring Group and 12.8 min (SD = 7.4) for the Display Unit-Monitoring Group.

8.6. Discrepancy between subjective and objective SOL

To index misperception of SOL, a discrepancy score was calculated by subtracting the objective from the subjective SOL estimates, such that a positive value denotes an overestimation, a negative value an underestimation. As depicted in Fig. 1, no significant main effect was observed for Group or Night. But there was a significant group by night interaction, F (1, 35) = 4.3, $p<0.05$, such that on the experimental night, the degree of SOL overestimation demonstrated by the Clock-Monitoring Group ($M = 24.3$, SD = 20.0) was greater than the Display Unit-Monitoring Group ($M = 10.8$, SD = 13.8) ($p<0.05$; $ES = 0.78$, $power = 0.76$). No similar between-groups difference was noted at baseline (Clock-Monitoring Group: $M = 16.4$, SD = 13.6; Display Unit-Monitoring Group: $M = 16.0$, SD = 10.4).

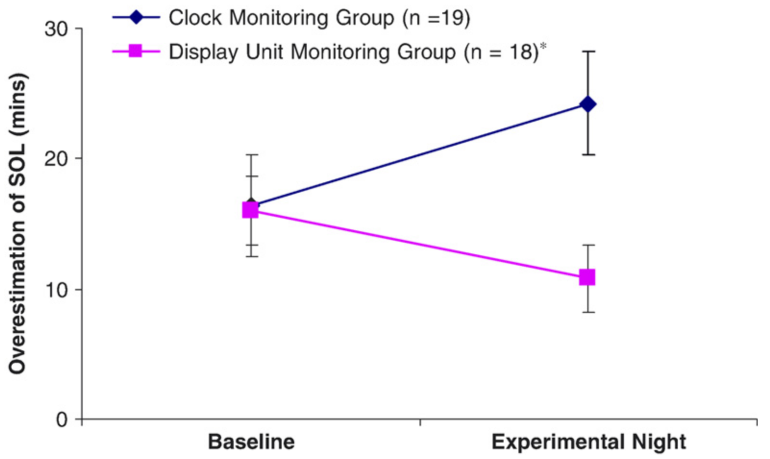

Fig. 1. Overestimation of SOL by group and night. *Note*: *Due to data file corruption, the sample size of the Display Unit-Monitoring Group was reduced from 19 to 18 for the above analysis.

9. Discussion

Consistent with the first hypothesis, the Clock-Monitoring Group had a higher pre-sleep worry score on the experimental night relative to the baseline night. Further, it was evident from the impact ratings that the clock-monitoring task was more worry provoking compared to the display unit-monitoring task. These findings, together, lend support to the suggestion that monitoring for sleep-related threat fuels worry (Harvey, 2002) and provide an empirical rationale for advising patients with insomnia to put the clock out of view whilst trying to get to sleep (Bearpark, 1994; Hauri, 1991; Morin, 1993). Interestingly, the Display Unit-Monitoring Group showed a significant decrease in their pre-sleep worry on the experimental night relative to the baseline night. According to cognitive models of attention (Baddeley, 1986; Shallice, 1988), the execution of information processing tasks rely on limited capacity. It is plausible that the digit display unit monitoring was a task so engaging that it occupied most of the cognitive space available, thereby providing an effective distractor from unwanted pre-sleep worries. This interpretation is consistent with findings of a previous experimental study (Harvey & Payne, 2002).

Regarding the impact of clock monitoring on sleep, only the subjective sleep data (as provided by sleep diary), not the objective sleep data (as provided by actigraphy), suggested that the Clock-Monitoring Group experienced a longer SOL compared to the Display Unit-Monitoring Group. These findings are in partial accordance with the second hypothesis that the Clock-Monitoring Group would take longer to get to sleep than the Display Unit-Monitoring Group. There are at least two possible explanations for the disconcordance between the subjective and objective sleep estimates. First, it may be argued that the lack of a corresponding increase in objective SOL estimates in the Clock-Monitoring Group is an artifact of the insensitivity of actigraph in detecting quiet wakefulness. However, this account is not entirely convincing as corresponding increases in objective SOL were detected in the monitoring groups in Experiment 1. Future research employing polysomnography would clarify this issue. Second, it is possible that *subjective* sleep perception and *objective* sleep are two separate response systems that do not react to pre-sleep monitoring and worry to the same extent. Regardless of the reason, this pattern of findings is consistent with previous research indicating greater reactivity in subjective sleep measures relative to objective sleep measures (e.g., Edinger, Wohlgemuth, Radtke, Marsh, & Quillian, 2001; Haynes, Adams, & Franzen, 1981). The findings of the present study hint at the 'potential importance of considering subjective and objective data as separate factors in explanatory models' (Wicklow & Espie, 2000, p. 690).

The third hypothesis was that clock-monitors would exhibit more misperception of sleep relative to display unit-monitors. In support, the discrepancy between the subjective and objective estimates of SOL in the Clock-Monitoring Group (mean SOL overestimation = 24.3 min) was greater compared to the Display Unit-Monitoring Group (mean SOL overestimation = 10.8 min) on the experimental night. Extending the findings of Experiment 1, these results suggest that monitoring for sleep-related threat, instead of a neutral object, during the pre-sleep period contributes to misperception of sleep (Harvey, 2002). It is plausible that, as suggested by Borkovec (1982), the pre-sleep worry (triggered by monitoring for sleep-related threat) constitutes the psychological basis for distorted perception of time. Consistent with Borkovec's suggestion, we found an increase in the pre-sleep worry score from baseline to the experimental night to be positively correlated with the increase in SOL overestimation ($r = 0.54$, $p < 0.001$, two-tailed). Of course, it is recognised that correlation does not implicate causality nor suggest the direction of the relationship. However, we note that empirical evidence not reliant on correlation has begun to accrue suggestive of pre-sleep cognitive arousal causing misperception of sleep (e.g., Tang & Harvey, 2004a, b, 2005).

To maximise methodological rigour, the present study chose to examine the impact of clock monitoring by experimentally assigning participants to monitor the clock during the pre-sleep period. Further investigation is warranted to examine whether or not the impact of clock monitoring vary as a function of people's natural tendency to monitor the clock. Also, the present experiment limits its scope of investigation to sleep-related worries as one mechanism mediating sleep difficulty. Future research should consider exploring the effect of clock monitoring on non-sleep-related worries, physiological arousal (Bonnet & Arand, 1992), and cortical arousal (Perlis, Giles, Mendelson, Bootzin, & Wyatt, 1997), which have also been put forward as possible mechanisms mediating sleep onset and sleep perception. Finally, the present experiment employed a relatively small non-treatment-seeking insomnia sample drawn from a university town. This might have led to relatively low effect sizes and observed powers on several analyses. The extent to which the current findings can be generalised to treatment-seeking insomnia patients remains to be determined in future studies using a larger and more representative sample.

10. Conclusion

This paper has presented two experiments that examined the role of clock monitoring in insomnia. Whilst mixed results were found for the relationship between clock monitoring and objective sleep, evidence from both experiments confirms the association between clock monitoring, pre-sleep worry and subjective sleep. Specifically, it was found that participants instructed to monitor the clock as they fell asleep reported increased pre-sleep worry and longer SOL and overestimated their SOL, compared to participants instructed not to monitor the clock or to perform a control monitoring task (i.e., to monitor a digit display unit). These findings are consistent with previous clinical observations that clock monitoring during the pre-sleep period is not conducive to sleep (Bearpark, 1994; Hauri, 1991; Morin, 1993) and provide empirical support for the hypothesis that monitoring for sleep-related threat, in this case the clock, contributes to insomnia by fuelling pre-sleep worry and exacerbating misperception of sleep (Harvey, 2002). They also add to the evidence that has amassed recently on the importance of attentional processes in chronic insomnia (e.g., Jones, Macphee, Broomfield, Jones, & Espie, 2005; Neitzert Semler & Harvey, 2004, in press; Taylor, Espie, & White, 2003).

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