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Misperception of sleep can adversely affect daytime functioning in insomnia

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Abstract

This experiment was designed to investigate the relationship between subjective perception of sleep and daytime processes in primary insomnia. Twenty-two individuals with primary insomnia received positive or negative feedback about their sleep, immediately on waking, on three consecutive mornings. The positive feedback was that last night's sleep was good quality. The negative feedback was that last night's sleep was poor quality. Objective sleep on each of the three nights was estimated by actigraphy and did not differ across the three nights or the two feedback conditions. Negative feedback (based on 32 nights of data) was associated with more negative thoughts, sleepiness, monitoring for sleep-related threat, and safety behaviours during the day, relative to positive feedback (based on 34 nights of data). These results indicate that the impaired daytime functioning reported by insomnia patients is maintained, at least in part, by subjective perception of sleep.

1. Introduction

By definition, patients with chronic insomnia report impairment in daytime functioning as a consequence of their sleep disturbance (American Psychiatric Association, 1994). Commonly reported symptoms include sleepiness, tiredness, difficulty functioning socially, impaired

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concentration, and memory problems (Roth & Ancoli-Israel, 1999). While such reports are ubiquitous, they have proven difficult to document on objective testing.

The Multiple Sleep Latency Test (MSLT) indexes daytime sleepiness by measuring speed of falling asleep on each of five naps throughout one day. Despite the MSLTs proven sensitivity to the effects of sleep deprivation (Stepanski, Zorick, Roehrs, & Roth, 2000), most studies using the MSLT have been unable to detect evidence of heightened sleepiness in people with insomnia, relative to good sleepers (e.g., Stepanski, Lamphere, Badia, Zorick, & Roth, 1984; see also Riedel & Lichstein, 2000 for review). Pupillometry, which measures pupil diameter and constriction, is another widely accepted method of objectively assessing daytime sleepiness. While some investigators have reported that people with insomnia show greater sleepiness than good sleepers using pupillometry, the differences were small (e.g., Lichstein & Johnson, 1994) and subsequent studies reported no differences (e.g., Lichstein & Johnson, 1996). Finally, the majority of studies using neuropsychological tests have shown no differences in performance between people with insomnia and good sleepers (e.g., Edinger et al., 1997; Schneider-Helmert & Kumar, 1995), although there are some exceptions (e.g., Bonnet & Arand, 1995).

How can we account for this puzzle? On the one hand patients with insomnia honestly and persistently report significant daytime impairment, yet this has been difficult to verify objectively. We suggest four potential solutions to this puzzle. First, perhaps the measures employed lack sensitivity. However, this seems unlikely as MSLT, pupillometry, and neuropsychological testing are all established indices of sleep deprivation. A second potential solution is that the sleep abnormalities characteristic of insomnia may be evident only on very detailed analysis of EEG during sleep, a possibility that is currently being explored (Perlis, Smith, Andrews, Orff, & Giles, 2001). A third solution is that differences have not reached significance because of methodological problems, such as small sample sizes and the lack of screening for comorbid psychiatric and/or sleep disorders (Riedel & Lichstein, 2000). A fourth solution, and the one that is the focus of the present paper, is that because many patients with insomnia appear to underestimate how much sleep they get in total and overestimate the impact of sleep loss the following day (see Chambers & Keller, 1993 for review), a tendency to misperceive sleep and its consequences may be an important process that contributes to the maintenance of insomnia (Harvey, 2002). Such an account would bring insomnia into line with a range of other psychological disorders known to be characterised by ‘distortions in reality’ (Beck, 1976, p. 218); people with anorexia nervosa think they are fat when they are actually very underweight, people with panic disorder think they are having a heart attack when they are in fact experiencing symptoms of anxiety, and people with hypochondriasis think they are suffering from a threatening illness when they are healthy.

In a recent cognitive model, we have tried to account for how a tendency toward misperceiving sleep and its consequences for the subsequent day may arise by suggesting that immediately on waking people with insomnia typically conclude that they have not obtained sufficient sleep and that this triggers a series of cognitive processes including; excessive worry and distress (e.g., ‘I'm never going to cope today’); monitoring for sleep-related threat (e.g., sore head, weak muscles, backache), and the use of safety behaviours (e.g., cancel appointments for the next day and stay in bed to catch up on sleep). Each of these processes contributes to impaired daytime functioning; worry and distress interfere with satisfying and effective performance (Eysenck, 1982); monitoring for sleep-related threat increases the detection of ambiguous cues that are then misinterpreted (Clark, 1999); and the use of safety behaviours interferes with functioning, maintains dysfunctional beliefs and increases the probability that a feared outcome will occur (Salkovskis, 1991). In other words, a cascade of cognitive processes culminate in *perceived* daytime impairment (if sufficient sleep was obtained on the previous night) or *worsens* the daytime impairment (if insufficient sleep was obtained on the previous night). These proposals echo Morin's (1993) suggestion that insomnia is fuelled by cognitive and emotional arousal combined with the misattribution of daytime impairment to inadequate sleep, and Riedel and Lichstein's (2000) proposal that "psychological distress could produce a negative cognitive set that causes people with insomnia to underestimate their ability to function during the day" (p. 289).

The present paper describes an experiment designed to capture the proposed relationship between subjective perception of sleep and daytime processes in primary insomnia. The study employed a 2 (Feedback: negative, positive) by 3 (Day: 1, 2, 3) within-subjects design to experimentally manipulate subjective perception of sleep over three consecutive days. Immediately on waking, individuals with primary insomnia were presented with either negative feedback (last night's sleep was poor quality) or positive feedback (last night's sleep was good quality). Based on the cognitive model described above, it was predicted that relative to positive feedback negative feedback, would trigger more negative thoughts, increased monitoring for sleep-related threat, and increased use of safety behaviours. In addition, it was predicted that participants would report more sleepiness on negative feedback, days relative to positive feedback days.

2. Method

2.1. Participants

Participants were university staff and students diagnosed with DSM-IV defined primary insomnia (American Psychiatric Association, 1994). Ninety-eight individuals completed and returned a screening questionnaire, 65 of whom were invited to participate having indicated that they had difficulty sleeping at least three nights per week in the past month and that they were currently concerned about this problem (the initial criteria for selecting individuals with insomnia). Thirty-three respondents attended the first session. The others did not respond to the invitation ($n=23$) or cancelled their scheduled appointment ($n=9$).

In the absence of a psychometrically validated alternative, a structured clinical interview, the Insomnia Diagnostic Interview (IDI), was used to determine the presence of primary insomnia. The IDI is comprised of five sections designed to carefully assess for the presence of each of the five DSM-IV criteria for primary insomnia. To be included in the present study, participants must have met all of these criteria in addition to the further requirement that the sleep disturbance must have occurred at least three nights per week over the past month. As a diagnostic check, patients must have scored more than 5 on the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). Buysse et al. (1989) have demonstrated that this cutoff identifies a clinically significant sleep disturbance with 89.6% sensitivity and 86.5% specificity. Reasons for exclusion from the study were: not meeting full diagnostic criteria for insomnia ($n=3$), current depression (a stipulation of the ethics committee; $n=1$), being unable to participate due to work-related demands ($n=1$), and not believing the manipulation ($n=6$). The final sample comprised 22 individuals with insomnia

(17 females, 5 males). Thus, we analysed 34 observations of the impact of the positive feedback condition and 32 observations of the impact of the negative feedback condition.

2.2. Materials

Actigraphy. A Mini-Motionlogger actigraph (supplied by Ambulatory Monitoring Inc.) was used to estimate objective sleep throughout the experiment. The actigraph is a small wristwatch-like device that senses and stores information about physical motion. The recorded information is later downloaded into software (Action-W) that scores the sleep/wake cycle. Data were collected in Zero-Crossing Mode using 60-s epochs. Compared to polysomnographically measured sleep, the 'gold standard', there is strong agreement in normal adults (above 90%; Jean-Louis, Kripke, Mason, Elliott, & Youngstedt, 2001). Actigraphy is a useful and non-intrusive instrument to measure the sleep/wake schedule (DeSouza, Benedito-Silva, Pires, Poyares, Tufik, & Calil, 2003). Relative to polysomnographic sleep estimates, the epoch-by-epoch agreement rate for sleep and wakefulness detection in adult good sleepers ranges from 74% to 98% (Reid & Dawson, 1999; Sadeh, Sharkey, & Carskadon, 1994; Ancoli-Israel, Clopton, Klauber, Fell, & Mason, 1997). The correlation between actigraphic and polysomnographic estimates ranges from .77 to .98 for SOL and from .82 to .90 for TST in adult good sleepers (Cole, Kripke, Gruen, Mullaney, & Gillin, 1992). Actigraphy is highly sensitive (87–99%; Reid & Dawson, 1999; Kushida, Chang, Gadkary, Guilleminault, Carrillo, & Dement, 2001; Sadeh, Hauri, Kripke, & Lavie, 1995) in detecting sleep epochs identified by polysomnography, it may however be less reliable at detecting wake (specificity: 28–90%; Reid & Dawson, 1999; Kushida et al., 2001; Sadeh et al., 1995). As will be discussed further in the limitations of the discussion, actigraphy may not be as accurate in some circumstances, such as among participants who lie immobile for an extended period of time.

"Electronic Display Unit" (EDU). The EDU is a small one-line text message pager unit (model: Ericsson Alpha 878i, supplied by British Telecom Inc.). As a disguise, the pager was refitted into a grey plastic box with a small window machined out so that only the liquid crystal display of the pager was visible.

2.3. Procedure

Approval for the study was obtained from the departmental ethical review board.

Session 1. Participants gave written informed consent to wear the actigraph, record their EDU feedback, and complete daily diaries for three consecutive days. They were reminded that they were free to withdraw from the study at any time. The IDI was administered to assess for presence of insomnia and the Structured Clinical Interview for the DSM-IV (SCID; Spitzer, Williams, Gibbon, & First, 1996) was employed to assess comorbidity. Participants then completed the PSQI (Buysse et al., 1989), the Beck Depression Inventory (BDI; Beck, Ward, Mendelsohn, Mock, & Erbaugh, 1961), the Spielberger State-Trait Anxiety Inventory (STAI; Spielberger, Gorusch, Lushene, Vagg, & Jacobs, 1983), and the Penn State Worry Questionnaire (PSWQ; Meyer, Miller, Metzger, & Borkovec, 1990).

Participants were fitted with the actigraph, which they were asked to wear for three consecutive nights. They were also given the EDU to place by their bedside. They were told that the actigraph would record their sleep quantity and sleep quality each night and that a summary of this information, translated into a 'sleep quality score', would be transmitted from the actigraph to the EDU each morning via a wireless communication system. The transmission of information from the EDU to the actigraph was explained to function on the basis of an infrared system, similar to that used in mobile telephones. Participants indicated their planned wake time for the three days and were informed that the transmission of feedback would be programmed through a central computer to occur automatically at that time each morning. Each participant also received nine diaries, labelled as follows: 'Day 1—On Waking Diary', 'Day 1—Midday Diary', 'Day 1—Evening Diary', 'Day 2—On Waking Diary', 'Day 2—Midday Diary', 'Day 2—Evening Diary', 'Day 3—On Waking Diary', 'Day 3—Midday Diary', and 'Day 3—Evening Diary' (content described below). The participants were asked to complete the On Waking Diary immediately on waking, the Midday Diary between noon and 1 p.m., and the Evening Diary between 6 p.m. and 8 p.m. each day.

While informed that the EDU feedback was generated by the actigraph recordings, in reality, participants were randomly assigned to receive a fully counterbalanced, pre-determined sequence of 2 negative and 1 positive feedback message *or* 2 positive and 1 negative feedback message (order of the three in each case was counterbalanced). The feedback sequences were assigned by consecutive order of recruitment (not by veridical sleep). The negative feedback was "Sleep Quality = 1" and the positive feedback was "Sleep Quality = 4".[1] The following scale was printed on the face of the EDU to facilitate accurate interpretation of the feedback: 1 = poor sleep quality, 2 = fair sleep quality, 3 = moderate sleep quality, 4 = good sleep quality, 5 = excellent sleep quality.

On Waking Diary. Participants recorded the date, time, and EDU feedback received. To enhance the believability of the feedback, the participants were intentionally not required to record their own subjective estimates of sleep.

Midday Diary. This diary comprised two sections that instructed participants to answer with reference to the period "from the moment you woke up until right now". To index *negative thoughts*, participants rated the extent to which each of 22 negative sleep-related thoughts came to mind (e.g., 'I can't cope today', 'I didn't get enough sleep last night', 'I feel tired', 'I must wake up somehow'; response scale: 0 = *not at all* to 10 = *very much*). The administration of this scale to an independent sample of 96 individuals with a clinically significant sleep disturbance (CSD) and 38 normal sleepers (NS) yielded good internal consistency ($\alpha = .95$) and test–retest reliability ($r = .76$). Also, the CSD group reported significantly higher scores than the NS group, $t(132) = 5.47$, $p < .001$ [CSD: $M = 4.2$, SD = 2.1; NS: $M = 2.4$, SD = 1.5] (Semler, 2002). The mean of the 22 ratings will be referred to as the Midday Negative Thoughts Score. The items that comprised this scale were drawn from the files of patients treated at the Oxford Centre for Insomnia Research and Treatment and from previous studies that have documented the negative thoughts experienced by patients with insomnia (e.g., Coyle & Watts, 1991; Espie, Brooks, & Lindsay, 1989; Fichten, Libman, Creti, Amsel, Tagalakis, & Brender, 1998; Harvey, 2000; Watts, Coyle, & East, 1994; Wicklow & Espie, 2000).

Section two assessed *sleepiness* with the Stanford Sleepiness Scale (SSS; Hoddes, Dement, & Zarcone, 1972). The SSS involves choosing one of seven statements to describe current sleepiness (scored 1–7). This score will be referred to as the Midday Sleepiness Score.

Evening Diary. This diary comprised four sections. The first two assessed negative thoughts and sleepiness and were identical to the Midday Diary except that participants were instructed to

[1] A rating of "5" was not adopted as pilot testing indicated it was not believable.

answer with reference to the period "from the time you completed the midday diary until right now". The mean scores generated will be referred to as the Evening Negative Thoughts Score and Evening Sleepiness Score. Two additional sections instructed participants to answer with reference to the period "from the time you woke up until right now". These sections were only included in the Evening Diary to minimise time required to complete the Midday Diary and thereby maximise compliance. Section three indexed *monitoring for sleep-related* threat. Participants were asked to rate the extent to which they monitored each of 16 body sensations (e.g., 'heavy or sore eyes', 'feelings of tiredness or heaviness in your body', 'noticed muscle aches') and each of 14 aspects of their daytime functioning (e.g., 'your concentration being affected', 'your productivity being affected'). The response scale for each item was 0 = *not at all* to 10 = *very much*. In an independent sample of 96 individuals with a CSD and 38 NS this scale has demonstrated good internal consistency ($\alpha = .93$) and test–retest reliability ($r = .67$) and the CSD group reported significantly higher scores than the NS group, $t(132) = 6.69$, $p < .001$ [CSD: $M = 3.8$, SD = 1.5; NS: $M = 2.3$, SD = 1.0] (Semler, 2002). The mean of the 30 ratings will be referred to as the Daytime Monitoring Score. For further details on the construction of the items that comprised this scale see Neitzert Semler and Harvey (2004, in press). Section four assessed the use of *safety* behaviour*s*. Participants were asked to rate the extent to which they used each of 17 safety behaviours throughout the day (e.g., 'took a daytime nap', 'rearranged/cancelled my social plans', 'did less exercise today because I was feeling tired'). The response scale for each item was 0 = *not at all* to 10 = *very much*. Among 96 individuals with a CSD and 38 NS this scale has good internal consistency ($\alpha = .82$) and test–retest reliability ($r = .69$) and that the CSD group reported significantly higher scores than the NS group, $t(132) = 5.63$, $p < .001$ [CSD: $M = 2.8$, SD = 1.6; NS: $M = 1.4$, SD = 1.1] (Semler, 2002). The mean of the 17 ratings was summed and will be referred to as the Daytime Safety behaviours Score. For further details on the construction of the items that comprised this scale see Ree and Harvey (in press).

Session 2. The actigraph and daily diaries were collected. In order to ascertain the effectiveness of the feedback manipulation the participants were asked two questions: (1) 'what did you think of the feedback you got each morning' and (2) 'did you believe that you were getting accurate feedback' (response scale: *yes, no*). The participants answered both questions consistently (i.e., both answers indicated they did believe the feedback or both answers indicated they did not believe the feedback). As noted earlier, six participants did not believe the feedback on one or more mornings and were therefore excluded. A comprehensive debriefing session was then conducted that included a thorough explanation of the true nature of the study and the purposes of the research. Careful attention was paid to ensure that individuals had not experienced any adverse effects as a result of their participation. Following this discussion, all participants received an honorarium for their involvement.

3. Results

3.1. Participant characteristics

The mean age of the participants was 21.4 (SD = 3.7) years and the mean duration of their sleep difficulties was 4.5 (SD = 4.5) years. The mean global score for the PSQI was 9.6 (SD = 2.6), for the BDI was 14.5 (SD = 8.4), for the STAI-S was 45.2 (SD = 12.6), for the STAI-T was 48.2 (SD = 11.3), and for the PSWQ was 58.4 (SD = 11.5). Based on the PSQI, the mean subjective total wake time[2] (TWT) for a typical night in the past month was 58.2 (SD = 33.3) minutes and the mean subjective total sleep time (TST) for a typical night in the past month was 6.8 (SD = 1.2) hours. Seventeen of the participants had a difficulty with sleep-onset, 7 had difficulty with waking after sleep onset and 2 had problems with both. In terms of Axis I comorbidity, 4 participants met criteria for one or more current disorders (generalised anxiety disorder = 2, social phobia = 2, specific phobia = 2). Given that insomnia is commonly comorbid with other psychological disorders (see Harvey, 2001 for review), individuals with comorbid conditions were not excluded on the basis that a 'pure' insomnia sample would not accurately reflect true insomnia (McCrae & Lichstein, 2001; Morin, Stone, McDonald, & Jones, 1994). However, the IDI includes procedures to ensure that the participants included in the study described insomnia as their *primary* problem.

3.2. Objective sleep estimates

Data from a total of 66 nights were available for analysis. Averaging across the negative feedback nights,[3] the mean objectively estimated TWT was 49.6 (SD = 40.1) minutes and the mean objectively estimated TST was 7.2 (SD = 1.0) hours. Averaging across the positive feedback nights (see footnote [3]), the mean objectively estimated TWT was 46.1 (SD = 48.3) minutes and the mean objectively estimated TST was 7.3 (SD = 1.1). To present this data in a slightly different way, averaging the objectively estimated sleep data across all participants: for Night 1 the mean objectively estimated TWT was 50.5 (SD = 52.4) minutes and the mean objectively estimated TST was 7.3 (SD = 1.2) hours; for Night 2 the mean objectively estimated TWT was 44.8 (SD = 42.2) minutes and the mean objectively estimated TST was 7.4 (SD = 1.0) hours; for Night 3 the mean objectively estimated TWT was 48.1 (SD = 38.9) minutes and the mean objectively estimated TST was 7.1 (SD = 1.0) hours. To test if there were differences in objective sleep estimates based on feedback or night, two separate 2 (Feedback: negative, positive) $\times$ 3 (Night: 1, 2, 3) repeated measures analyses of variance (ANOVA) were conducted, one for TWT and one for TST. No main effects or interactions reached significance. Because the data for TWT were positively skewed (skewness = 2.0), the data for TWT were logarithmically transformed. A repeated measures ANOVA of the transformed data indicated no significant main effects or interactions. That is, in the analyses to follow, differences observed as a function of feedback cannot be attributed to the estimated differences in objective sleep obtained during the experiment.

3.3. Daytime measures

Data from a total of 66 days were available for analysis (32 days following negative feedback, 34 days following positive feedback). All analyses were initially performed separately for the Midday Diary and the Evening Diary. Due to the close similarity of the results, the midday and evening scores were averaged and overall mean scores reported. These will be referred to as the Daytime Negative Thoughts Score and the Daytime Sleepiness Score. The overall mean scores for

[2]Sleep onset latency plus nighttime awakenings.
[3]Each participant contributed either 1 or 2 nights to this calculation.

Table 1
Mean daytime measures for the negative and positive feedback conditions across the three experimental days

Measure	Negative feedback			Positive feedback		
	Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
Daytime negative thoughts score	4.5 (2.0)	4.4 (2.1)	4.6 (1.9)	3.4 (1.7)	3.3 (2.2)	3.1 (1.9)
Daytime monitoring score	4.5 (1.0)	4.4 (1.5)	3.8 (1.0)	3.4 (1.5)	3.2 (1.3)	4.2 (1.6)
Daytime safety behaviors score	8.5 (4.3)	8.7 (3.3)	7.3 (3.4)	7.9 (2.8)	6.4 (2.7)	7.0 (2.8)
Daytime sleepiness score	3.9 (0.8)	4.1 (1.4)	4.5 (1.4)	3.6 (1.7)	3.5 (1.0)	3.6 (1.2)

Note. Mean values are reported with standard deviations in parentheses.

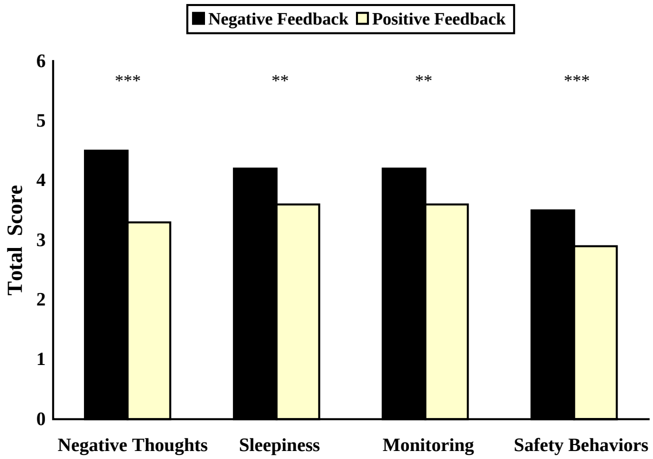
these measures, along with the Daytime Monitoring Score and Daytime Safety Behaviours Score are presented in Table 1. To examine the effects of feedback on daytime processes, a series of 2 (Feedback: negative, positive) $\times$ 3 (Day: 1, 2, 3) repeated measures ANOVAs were conducted for each of the dependent measures. There was a significant main effect for Feedback for all daytime variables. As depicted in Fig. 1, negative feedback was associated with more negative thoughts, $F(1, 21) = 18.42$, $p < .001$, more monitoring, $F(1, 21) = 11.00$, $p < .01$, greater use of safety behaviours, $F(1, 21) = 12.61$, $p < .001$, and greater sleepiness, $F(1, 21) = 9.15$, $p < .01$, during the day relative to positive feedback. There were no significant effects for Day and no interactions.

3.4. Relationship between objective sleep estimates and feedback condition

The next analysis was conducted to address the possibility that the results were affected by a match or mismatch between the feedback given and actual sleep obtained. Following Edinger et al. (2000), and based on Bonnet's (1994) finding that subjective sleep complaints occur when a person sleeps for less than 6.5 h per night, we created four subgroups.

The first two groups represent the data for the nights when there was a match between the sleep obtained and the feedback received. These two groups were defined as (1) positive feedback *and* TST over 6.5 h ($n = 26$ of the sample) and (2) negative feedback *and* TST under 6.5 h ($n = 9$ of the sample). These two subgroups will be referred to as Group 1 and Group 2, respectively. The second two groups represent the nights when there was a mismatch between the sleep obtained and the feedback received. These two groups were defined as (3) positive feedback *and* TST under 6.5 h ($n = 8$ of the sample) and (4) negative feedback *and* TST over 6.5 h ($n = 23$ of the sample). These two subgroups will be referred to as Group 3 and Group 4, respectively. We note at the outset that a limitation of this method of grouping is that it does not take into account that individual sleep requirements may vary widely (Edinger et al., 2000; Hauri, 1992). Nonetheless, the method has been successfully employed in previous research (Edinger et al., 2000) and provides a useful categorisation method for examining this important issue.

Planned independent samples *t*-tests were then conducted, for each of the four daytime measures, comparing (Group 1) positive feedback *and* TST over 6.5 h and (Group 3) positive feedback *and* TST under 6.5 h. The aim of this analysis was to determine if the effects of positive feedback varied if consistent with (i.e., a match) or contrary to (i.e., a mismatch) the objective



Note. Asterisks represent significant differences between the negative feedback and positive feedback conditions; **p < .01. ***p < .001.

Fig. 1. Mean daytime measures, collapsed across the three experimental days, for the positive and negative feedback conditions.

Table 2
Relationship between objective sleep estimates and feedback condition

Group	Negative thoughts score	Monitoring score	Safety behaviours score	Sleepiness score
1	3.5 (1.9)	3.9 (1.5)	3.2 (1.6)	3.7 (1.3)
2	4.8 (2.3)	3.9 (1.3)	3.2 (1.5)	4.3 (1.7)
3	2.6 (1.7)	2.8 (1.1)	1.9 (1.1)	3.2 (1.0)
4	4.4 (1.8)	4.4 (1.2)	3.6 (1.6)	4.1 (1.0)

Note. Mean values are reported with standard deviations in parentheses. Group 1 = positive feedback *and* total sleep time measured by actigraphy over 6.5 h ($n = 26$ of the sample); Group 2 = negative feedback *and* total sleep time measured by actigraphy under 6.5 h ($n = 9$ of the sample); Group 3 = positive feedback *and* total sleep time measured by actigraphy under 6.5 h ($n = 8$ of the sample); Group 4 = negative feedback *and* total sleep time measured by actigraphy over 6.5 h ($n = 23$ of the sample).

sleep obtained. If the actual sleep obtained is less important than the perception of sleep (i.e., the feedback), then we would expect this analysis not to reach significance. Indeed, there were no significant differences for negative thoughts, monitoring or sleepiness and the difference for safety behaviours, $t(29) = 2.16$, $p = .04$, was no longer significant when a Bonferroni adjustment was applied to control for multiple comparisons ($.05/4 = p < .0125$) (see Table 2 for mean values).

Planned independent samples *t*-tests were conducted, for each of the four daytime measures, comparing (Group 2) negative feedback *and* TST under 6.5 h and (Group 4) negative feedback *and* TST over 6.5 h. The aim of this analysis was to determine if the effects of negative feedback varied if consistent with (i.e., a match) or contrary to (i.e., a mismatch) the objective sleep obtained. If the actual sleep obtained is less important than the perception of sleep (i.e., the feedback), then we would expect this analysis not to reach significance. Indeed, there were no significant differences for negative thoughts, monitoring, safety behaviours, or sleepiness (see Table 2 for mean values).

Planned independent samples *t*-tests were conducted, for each of the four daytime measures, comparing (Group 3) positive feedback *and* TST under 6.5 h and (Group 4) negative feedback *and* TST over 6.5 h. The aim of this analysis was to determine the effects of positive and negative feedback where both contrary to the objective sleep obtained. If the actual sleep obtained is less important than the perception of sleep (i.e., the feedback), then we would expect this analysis to reach statistical significance. Indeed, the results did reach significance for negative thoughts, $t(29) = -2.42$, $p = .02$, monitoring, $t(29) = -3.19$, $p = .003$, safety behaviours, $t(29) = -2.78$, $p = .009$, and sleepiness, $t(29) = -2.13$, $p = .04$ (see Table 2 for mean values). That is, for all four variables daytime functioning was rated as worse (i.e., higher scores) for those who received negative feedback, even though they slept over 6.5 h, relative to a group who received positive feedback but slept less than 6.5 h. It is of note that when a Bonferroni adjustment was applied to control for multiple comparisons ($.05/4 = p < .0125$), only monitoring and safety behaviours remained significant.

3.5. Relationship between objective sleep estimates and daytime measures

To evaluate the extent to which the daytime measures observed were associated with the actual sleep obtained, Pearson's correlation coefficients were calculated between the estimate of objective total sleep time recorded by the actiwatch and each of the four daytime measures. A Bonferroni adjustment was applied ($.05/4 = p < .0125$). No significant correlations were observed for Night 1 (negative thoughts $r = -.07$, monitoring $r = .16$, safety behaviours $r = .17$, sleepiness $r = .6$), Night 2 (negative thoughts $r = -.15$, monitoring $r = .07$, safety behaviours $r = .10$, sleepiness $r = -.22$), or Night 3 (negative thoughts $r = .03$, monitoring $r = .43$, safety behaviours $r = .33$, sleepiness $r = .09$).

4. Discussion

The present study investigated the relationship between subjective perception of sleep and daytime processes in primary insomnia. The question posed was: Does distorting perception of sleep immediately on waking adversely affect daytime functioning? On days following negative feedback (that the sleep obtained was poor quality), participants reported more negative thoughts, greater sleepiness, more monitoring for sleep-related threat, and greater use of safety behaviours relative to positive feedback days (that the sleep obtained was good quality). These results are consistent with the proposal that impaired daytime functioning among insomnia patients is maintained, at least partly, by the subjective perception of inadequate sleep (Harvey, 2002). These results also support the proposed mechanism by which subjective perception is thought to operate; namely, by triggering a vicious cycle of cognitive processes that culminates in *perceived* daytime impairment (if sufficient sleep was obtained on the previous night) or *worsening* of the daytime impairment (if insufficient sleep was obtained on the previous night) (Harvey, 2002). The results also concur with previous correlational research showing associations between psychological variables and impaired daytime functioning (e.g., Alapin, Fichten, Libman, Creti, Bailes, & Wright, 2000; Moul, Nofzinger, Pilkonis, Houck, Miewald, & Buysse, 2002) and with theoretical discussions highlighting a role for cognitive and emotional factors during the day in the maintenance of insomnia (Morin, 1993; Riedel & Lichstein, 2000).

Can these findings be accounted for by the actual sleep obtained? Two lines of evidence converge to suggest that the answer to this question is ‘no’. First, there were no differences in the objective sleep estimates across the three days nor across the feedback conditions. Second, no significant correlations were observed between the estimates of objective total sleep time generated by the actiwatch and the daytime variables. In other words, the association between the feedback administered and the daytime variables cannot be attributed to the actual sleep obtained. Consistent with this conclusion, because we had estimates of the objective sleep obtained we were able to ascertain the impact of a match or mismatch between the feedback and objective sleep. The effects of positive feedback and negative feedback did not differ for days on which there was a match between the feedback and the objective sleep estimate and days on which there was a mismatch between the feedback and the objective sleep estimate. Further, all daytime functioning measures were rated as worse on days when the sleep obtained was adequate (over 6.5 h) but negative feedback was administered, compared to days when the sleep obtained was inadequate (under 6.5 h) but positive feedback was administered. However, we note that these analyses were limited by the small sample sizes and resultant insufficient power (retrospective power analyses ranged from .17 to .58).

This study raises a number of issues to be addressed in future research. First, the current design does not enable us to comment on whether the effects observed are due to the negative feedback, the positive feedback or both. Hence, a replication of this study that includes a no feedback control is required. Second, it is recognised that bias may have been introduced by the reliance on retrospective and self-report diaries to index daytime processes. However, the use of diaries is widely accepted as a useful method of obtaining clinical information about subjective experience (Espie, 1991). Further, the diaries used in the current study had all been validated in an independent sample (Semler, 2002). Nonetheless, the use of electronic diaries, completed at several time points each day, should be adopted in future studies.

The present findings must be interpreted in the light of several limitations. First, the participants included in the study did not undergo objective assessment for comorbid sleep disorders. However, the IDI includes a comprehensive set of questions to screen for sleep-related breathing disorders, narcolepsy, parasomnias, and circadian rhythm disorders. None of the participants responded affirmatively to any of these screening questions. Second, while all participants scored higher than 5 on the PSQI and met strict diagnostic criteria for primary insomnia, the sample was recruited from a university population and thus may not be representative of the clinical insomnia population. Future studies should endeavour to replicate the current findings in treatment-seeking samples. Third, as noted earlier, it is emphasised that actigraphy is a less reliable estimate of sleep in individuals who lie immobile for long periods (e.g., insomnia patients and clinically depressed patients). Accordingly, the analyses presented on the relationship between objective sleep estimates and feedback condition are preliminary and require confirmation once the actigraphy algorithm for scoring sleep is adjusted to take account of the unique features of the sleep of patients with insomnia. Finally, to enhance the believability of the feedback, participants were intentionally not required to record their own subjective estimates of sleep. The disadvantage of this decision is that it is not possible to quantify occasions when there was a match versus mismatch between the feedback and the subjective experience of sleep.

Delving into these kinds of complexities is theoretically interesting and should be addressed in future research.

In conclusion, the present study indicates that subjective perception of the quality and quantity of sleep obtained, immediately on waking, has an important impact on daytime functioning among people with insomnia. If these initial results are replicated with a treatment seeking sample, consideration should be given to teaching insomnia patients to hold less credence in their subjective perception of sleep (see Tang & Harvey, 2004, for a possible method) and should emphasise the adverse consequences, for daytime functioning, of concluding that the sleep obtained is adequate.

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