Running Head: IMPROVING SLEEP BEHAVIOURS

The role of self-monitoring and response inhibition in improving sleep behaviours

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Abstract

Young adults tend to have poor sleep, which may be a result of poor self-regulation. This study investigated whether manipulating two aspects of self-regulation: self-monitoring and response inhibition could improve sleep behaviours. University students (N=190) were randomly allocated to complete 1) a self-monitoring sleep diary and response inhibition training, 2) a sleep diary only, or 3) a control questionnaire daily for a period of 7 days. Outcome measures were three sleep hygiene behaviours previously found to be particularly important in this population: avoiding going to bed hungry and thirsty, avoiding anxiety and stress provoking activity before bed, and making the bedroom and sleep environment restful. Those who completed diary based self-monitoring successfully avoided anxiety and stress provoking activity before bed more frequently than control participants, corresponding to a medium effect size, and further development may provide a simple intervention to improve aspects of sleep and other health behaviours. There was no incremental effect of response inhibition training. Modified response inhibition training tasks may be worth investigating in future research.

KEYWORDS: self regulation, sleep hygiene, self monitoring, response inhibition, young adults

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Introduction

Sleep Hygiene and University Students

A majority of young people have irregular and insufficient sleep, with tension and stress being the greatest predictor of poor sleep quality (1). University students also tend to have poor sleep (2, 3), partially due to a conflict between university, work and social demands and natural circadian rhythms, as well as from anxiety and stress (4). University students are therefore at increased risk of poor sleep and sleep-related illness, and represent an important population within which to attempt to improve sleep.

Sleep hygiene refers to behaviours that are conducive to healthy sleep, such as sleep regularity, avoiding caffeine, alcohol, and sugary foods before bed, not engaging in stimulating behaviours before bed, and using the bed for sleep and sex only (5). Whilst many aspects of sleep quality such as sleep disturbances and depth of sleep are uncontrollable and difficult to measure, sleep hygiene behaviours are generally specific, modifiable and controllable. Kor and Mullan (3) identified three sleep hygiene behaviours that university students rated as most pertinent to them: avoiding going to bed hungry and thirsty, avoiding stress and anxiety provoking activity before bed, and making the bedroom and sleep environment restful. These behaviours were thus targeted in the current study.

Sleep Hygiene and Self-regulation

The impact of sleep and sleep hygiene on self-regulation has been relatively well-studied (e.g. 6, 7). Indeed, research has found that those with poor sleep hygiene have a reduced self-regulatory capacity and subsequently had less work engagement (8). However, little research has explored the role of self-regulation in performing behaviours that facilitate good sleep, even though the importance of self-regulation in sleep behaviours has been noted

(9). According to Hall and Fong (10), health behaviours (such as sleep habits) may have a temporal discrepancy between immediate costs and long-term benefits, and therefore maintaining these behaviours requires self-regulation (11). Other researchers have also acknowledged the importance of the relationship between sleep hygiene behaviours and self-regulation (12, 13). In particular, sleep behaviours such as making the sleep and bedroom environment restful require inhibition of a dominant or preferred response (such as taking the mobile phone to bed or having the TV on) in order to carry out the goal-directed behaviour (making the bedroom restful), with gains from this process not occurring until later (such as feeling rested in the morning or less tired at the end of the week). Therefore, self-regulation may be important for sleep hygiene.

There has been preliminary research exploring the role of self-regulation (and response inhibition) in predicting behaviour, including sleep (11). In a community sample, executive function (using the Stroop task) predicted sleep habits above demographics, education level, and IQ (11). Kor and Mullan (3) investigated the role of response inhibition in predicting sleep hygiene in university students. Response inhibition was measured using a computerised GNG task, which required students to respond to rectangles of a certain colour, whilst inhibiting responses to rectangles of a different colour. GNG response inhibition significantly predicted sleep hygiene, and explained an additional 16% of the variance in sleep hygiene behaviour after motivational factors (such as intention and perceived control) were taken into account. These findings suggest that response inhibition may play a role in explaining sleep behaviours in university students.

One way to change self-regulation is to encourage self-monitoring through diary keeping (14). Within Control Theory, self-monitoring is a mechanism that produces behaviour change by creating a ‘discrepancy reducing feedback loop”, in which individuals can reduce the discrepancy between their current state and desired state by observing the

consequences of their behaviour and altering their behaviour as necessary (15). Self-monitoring can also serve as a cue or prompt to engage in desired goal-directed behaviours (16). Self-monitoring via keeping a diary Diaries have been used extensively as behaviour change tools for food related behaviours (17, 18). There have also been a limited number of recent interventions that have shown that diaries can improve self-regulation and behaviour. For example, a study diary was successfully used to promote self-monitoring and subsequently improve self-regulation surrounding exam stress (19). In another study, financial self-monitoring was encouraged through spending diaries, which improved self-regulatory capacity (20).

Within sleep research, diaries have traditionally been used as behaviour measures (21, 22), however, Adachi et al. (23) have employed self-monitoring to improve sleep. A month long self-help program that consisted of self-monitoring, as well as behavioural goal-setting and educational resources was designed to target both sleep hygiene behaviours and actual sleep. The self-monitoring component included recording whether their performance on target goal behaviours was good, fair or poor. One year following the intervention, four of nine sleep hygiene behaviours had improved, and corresponded with an improvement in aspects of sleep quality such as total sleep time.

Another way to change self-regulation is to prompt practice (14). Within the Strength Model of Self-Control, self-regulation has been proposed to be a limited resource, that can become depleted, but can also be strengthened with repeated use, much like a muscle (24). Thus, by practicing tasks that require self-regulation, this ‘muscle’ can be trained (25). Indeed, research has found that self-regulatory resource depletion mediates the relationship between poor sleep-hygiene and poor work engagement (8). There has been a small but growing body of research by Houben and colleagues in which practising executive function and response inhibition tasks such as the GNG has improved health behaviours in laboratory

settings. For example, Houben et al. (26) found that performing working memory training tasks over a period of 25 days, reduced alcohol consumption one month later, compared to a control group. Furthermore, response inhibition training as short as one session has been shown to be effective. Both alcohol consumption (27) and chocolate consumption (28) have been reduced relative to controls, with single-session practice of a GNG with no-go (inhibition) trials paired to alcohol cues and chocolate respectively. In another study, Houben (26) found that practising an alternative response inhibition task (a modified stop-signal task) reduced subsequent intake of potato chips, peanuts and chocolates for those low in inhibitory control, compared to a control group. It is therefore possible that a brief GNG-based manipulation could also improve sleep hygiene behaviours. However, previous research has not investigated whether more general response inhibition training (i.e. not behaviour specific) can lead to behavioural changes. If general training is found to be effective, then it may suggest that the type of stimuli is not an active ingredient in such training. Other forms of self-regulation training (19) have produced general improvements in both self-regulation and health behaviours, and therefore general response inhibition training may also provide an avenue for broader behavioural improvements or targeting multiple behaviours at once.

Aims and Hypotheses

Given the effectiveness of Adachi et al.'s (23) intervention (which included self-monitoring) in targeting aspects of sleep, the current study firstly explored whether diary-based self-monitoring techniques alone could improve self-regulation and sleep hygiene. It was hypothesised that keeping a sleep diary for a period of 7 days would improve response inhibition as well as sleep hygiene above the effects of an unrelated control task.

Secondly, given recent research suggesting that response inhibition training can improve health behaviours, this research was extended to explore whether response inhibition training has an additive effect in improving self-regulation and sleep hygiene when combined

with diary self-monitoring. It may be that self-monitoring training serves to keep sleep goals in mind, whilst the response inhibition training increases available self-regulatory resources to enable goal-directed behaviour. It was therefore hypothesised that those who received GNG response inhibition training in addition to diary-based self-monitoring would have improved response inhibition and sleep hygiene compared to those who completed only diary-based self-monitoring.

Method

Recruitment, Procedure and Design

One hundred and ninety first year university students participated in the study in exchange for course credit. In order to be eligible for the study students had to be 18 years or older, have written and spoken English, and have daily access to the internet on a *Windows*-based computer. Students were ineligible to enrol in the study if they were undergoing treatment for a sleep disorder.

At baseline, participants completed demographic, response inhibition and sleep hygiene measures. Participants were then randomly allocated automatically via computer-based *LimeSurvey* software (29) to one of three between-subjects experimental groups, to complete: 1) a diary, 2) a diary and response inhibition training, or 3) a control survey daily for 7 days. Sleep hygiene behaviour and response inhibition were assessed again 15 days following baseline. As the entire experiment was completed over the internet with no experimenter contact, and responses were anonymous, the experimenters remained blind to the allocation of participants to experimental groups.

Manipulation

Sleep diary

Participants in both experimental groups completed a daily sleep diary, based on the Pittsburgh Sleep Diary (22). This diary was completed in *Microsoft Word*, and emailed to the

researcher daily via an email account created for this purpose. Participants were asked about the length and timing of their sleep, times woken during the night, and reasons for waking. In addition, participants were asked about any substances (e.g. tobacco and alcohol) consumed, exercise completed and naps taken on the previous day. Completed diaries were counted, and participants were excluded if they completed less than five of the seven sleep diaries. Of those in the sleep diary only condition, 84% completed the intervention component successfully.

Response inhibition training

In addition to the diary, participants in the second experimental group completed a computer based general GNG response inhibition training task daily. Red and green rectangles that were either horizontal or vertical flashed on the screen. Individuals were required to respond quickly to "go" trials (red rectangles), and inhibit responding for "no-go" trials (green rectangles). Participants completed 250 trials each day. Completion of each session of response inhibition training took approximately 10 minutes. Participants were sent both the GNG task and the diary in the same email, and could choose which they completed first. The data from participants in the sleep diary plus response inhibition training condition was retained if they completed five or more of the seven response inhibition training tasks in addition to five or more of the seven sleep diaries. Both intervention components were successfully completed by 61% of participants in this group.

Control

Participants allocated to the control group completed a daily questionnaire about other health related behaviours, such as fruit and vegetable consumption and sunscreen use. This questionnaire was developed by the authors, and is reported elsewhere (30). Each questionnaire lasted approximately 10 minutes. Of those assigned to the control, 62% successfully completed this component.

Measures

Behaviour measures

Three sleep-hygiene behaviours were investigated in the current study; making the bedroom/sleep environment restful, avoiding going to bed feeling hungry or thirsty, and avoiding anxiety and stress provoking activity before bed. These sleep hygiene behaviours were considered the most relevant to a similar sample of students at the same university. For more information about the procedure of selecting these behaviours, see Kor and Mullan (3).

Sleep hygiene behaviours were assessed with one item each: "*over the past week, how many days did you make your bedroom/sleep environment restful?*", "*over the past week, how many days did you avoid going to bed feeling hungry or thirsty?*", "*over the past week, how many days did you avoid anxiety and stress provoking activity before bed?*", with eight possible responses ranging from 0 to 7 days. These behaviours were investigated independently, as in the current study there was low reliability when they were combined (Cronbach's alpha= 0.50 and 0.38 for baseline and follow-up respectively).

Response inhibition

Two tasks commonly used to measure response inhibition were used. The GNG was used as a manipulation check, whilst the Stroop was used to measure changes in response inhibition.

The GNG was identical to the manipulation task. The variable of interest was *performance index*, calculated by taking the proportion of trials that are responded to correctly, and dividing this number by the average time taken to complete each problem (3). The baseline mean performance index for the GNG ranged from 12.50 to 21.15, with a mean of 18.50 (SD=1.04), with higher scores indicating better performance. This is comparable to the performance index of 21.69 (SD=35.52) reported by Kor and Mullan (3) using a similar sample.

The Stroop (31, 32) was used to measure response inhibition, as response inhibition and practice effects were potentially confounded in the GNG used as a manipulation check. The version of the Stroop used was completed over the internet, as validated by Linnman et al. (33), and participants used the keyboard to make their choices. The Stroop involved responding to the colour of incongruent and congruent colour-word combinations, and neutral trials in which only a patch of colour was presented. The variable of interest was *interference score* calculated as the difference in accuracy between incongruent and neutral trials (34). The baseline mean interference score for the Stroop ranged from -79.00 to 8.16, with a mean of -13.55 (SD=16.63), with lower (negative) scores indicating greater interference.

Data Analysis

Correlation and ANOVA analyses were used to identify whether demographic variables were potential confounders of response inhibition or sleep hygiene. For experimental analyses, two contrast variables were created to compare (1) both experimental groups to the control (i.e. contrast ratings: self-monitoring only (0.5), response inhibition and self-monitoring (0.5), control (-1)), to determine the effects of self-monitoring and (2) the experimental groups to each other (i.e. contrast ratings: self-monitoring only (-0.5), response inhibition and self-monitoring (0.5)), to determine the advantages of response inhibition training over self-monitoring effects. Regression analyses using these contrasts were applied to determine (1) the experimental effects on each of the sleep hygiene behaviours, (2) the effects on GNG response inhibition (as a manipulation check), and (3) the effects on Stroop response inhibition performance.

Results

Of the 190 participants who completed the initial survey, 128 (67%) completed the intervention and follow-up satisfactorily. There were no significant differences in baseline behaviour or response inhibition between those who dropped out and those who remained

(p≥.29). The final sample included 35 participants in the control group, 63 in the diary group, and 30 in the diary plus response inhibition training group. A liner regression sensitivity analysis suggested that the final sample was adequate to detect medium size hypothesized intervention effects (f^2 =0.12), with power of 0.8, and alpha of .05.

Of these participants, 79% were female, and ages ranged from 18 to 49, with a mean of 20 (SD=5.4). The greatest proportion of participants (44%) identified as Asian (or Asian-Australian), or Australian (43%). The majority of participants lived with their parents (82%) and had a professional (62%) as the head of the household.

At baseline, participants reported making their bedroom and sleep environment restful on 4.8 (SD=1.9) occasions, avoiding going to bed hungry or thirsty on 5.6 (SD= 1.5) occasions, and avoiding anxiety and stress provoking activity on 4.5 (SD=1.8) occasions over a week. There were no baseline sleep hygiene differences between groups (as shown in Table 1), nor differences in age, gender, or GNG performance (p>.05).

--INSERT TABLE 1 HERE--

Demographic Variables

Correlation and univariate ANOVA analyses were conducted to determine whether demographics were associated with sleep hygiene and response inhibition outcomes. Age, gender, type of living situation and qualification of head of household were not associated with baseline behaviour or response inhibition measures, however making the bedroom and sleep environment restful varied significantly depending on nationality, F (8,181) = 2.01, p=.047. Post-hoc comparisons using Tukey's procedure revealed no specific significant differences between groups, and therefore nationality was not controlled for in regression analyses. Response inhibition and the other sleep hygiene behaviours did not significantly vary according to nationality.

Experimental Results

Effects on behaviour

Three multiple regressions were conducted to test the effects of the experimental manipulations on the sleep hygiene behaviours (see Table 2). For each regression, past behaviour was added in the first step, followed by the two experimental contrasts in the second step. Neither contrast significantly predicted making the bedroom restful or not going to bed hungry or thirsty. However, there was a significant difference between the control and experimental groups for avoiding anxiety or stress-provoking activity before bed. Controlling for past behaviour, those in the experimental groups on average avoided anxiety and stress-provoking activity on 0.8 more days in a week than those in the control group, β=.18, t (n=124)=2.19, p=.03. Cohen's d for this result was 0.42, corresponding to a medium effect size. There was no difference between experimental groups for this behaviour.

--INSERT TABLE 2 HERE--

Response inhibition

To determine whether the GNG response inhibition training improved GNG performance, past GNG performance was first entered into a multiple regression, followed in the second step by a contrast comparing those who completed the response inhibition training to those in the control group. Past GNG performance was a significant predictor of follow-up GNG performance, β=.48, t(104)=4.83, p<.001. Controlling for past GNG performance, those in the response inhibition training group had a better GNG performance index than those in the control group, β= -.25, t(79)=-2.59, p=.011.

A similar multiple regression was then performed to determine training effects on Stroop performance. Past Stroop performance was a significant predictor of follow-up Stroop performance, β=.27, t(80)=2.48, p=.015. Controlling for past Stroop performance, there were no differences between the response inhibition training group and the control group (p=.16).

Discussion

The current study explored self-regulation in the context of sleep behaviours, and compared the effects of two self-regulation based experimental manipulations (diary self-monitoring and response inhibition training) on three sleep behaviours: avoiding going to bed hungry and thirsty, avoiding stress and anxiety provoking activity before bed, and making the bedroom and sleep environment restful.

Self-monitoring

Partial support was found for the hypothesis that keeping a sleep diary would improve sleep hygiene relative to the control group. There were no effects on making the bedroom and sleep environment restful, or on avoiding going to bed hungry or thirsty. However, participants in the experimental groups avoided anxiety and stress provoking activity before bed nearly once a week more than those in the control group, corresponding to a medium effect size. This is particularly important as stress has been implicated as a major factor of poor sleep (35). Thus reducing anxiety and stress provoking activity by a simple self-regulation behaviour such as keeping a sleep dairy may lead to better quality sleep and subsequently a range of other benefits such as reduced psychological strain (6).

The results suggest that avoiding anxiety and stress provoking activity before bed is modifiable through encouraging self-monitoring. Oaten and Cheng found that practising self-control through a study program improved study habits and a range of health behaviours such as tobacco and alcohol consumption and diet (19), and that a two month planned exercise program improved a range of health behaviours, other non-health behaviours, and self-regulation (36). Taken together, these results are promising, as they support self-monitoring as an avenue to improve general health behaviour. Diaries have not been used as a manipulation in sleep hygiene research before, and therefore the current research opens up new avenues for using diaries as a behaviour change tool, and particularly for developing sleep hygiene interventions.

Response Inhibition Training

The hypothesis that response inhibition training would incrementally improve sleep hygiene behaviour above the effects of the sleep diary was not supported. Those who practiced the GNG response inhibition task showed improved performance on this task above the control group, which suggests that task performance is malleable and can be improved with practice. However, there were also no changes in Stroop performance as a result of the response inhibition training, and the GNG improvement did not correspond to sleep hygiene behavioural changes.

That the response inhibition manipulation was ineffective is in contrast to the work of Houben and colleagues (26-28) who found similar manipulations conducted over shorter periods effective in improving health behaviours. One potential explanation is that response inhibition may have improved, as suggested by GNG scores, but may not be as relevant to sleep hygiene as originally anticipated. This is contrary to previous research (3) that found response inhibition predictive of the sleep hygiene. However, it is possible that sleep hygiene behaviours have some immediate benefits which provide motivation independently of response inhibition. The behaviours could therefore be intrinsically rewarding and not require inhibition of other more rewarding behaviours, which is supported by the moderately high levels of behavioural engagement at baseline indicating that sleep hygiene may actually be a prepotent response.

This explanation does not account for the lack of group differences in Stroop performance, as the GNG and Stroop are often both considered measures of response inhibition (37). However, it has been suggested that these tasks do not actually measure the same construct. For example, Fulham and Mullan (38) found that these tasks did not correlate (r=.02), suggesting that independence. Cheung et al. (37) noted that the GNG tends to measure ability to initially inhibit a prepotent response, whereas the Stroop measures the

ability to control disruptions from competing responses. Suchy (39) also suggested a distinction; that the Stroop involves response selection, inhibition and attentional vigilance, whereas GNG error measures only response inhibition. As a result changes in one task would not necessarily correspond to changes in the other. Thus, further research is necessary to explore whether the GNG and Stroop are similar enough to be considered alternative response inhibition measures, and whether alternative executive function components are more relevant to sleep hygiene.

Another possible explanation for the finding was that in the current study, the GNG was not specific to any particular behaviour, which may indicate that stimuli needs to be behaviour-specific in order to be effective. Houben and colleagues (26-28) have used behaviour-specific response inhibition tasks, whereby no-go (inhibition) trials were paired with behaviour-specific images (such as chocolate or alcohol). However, non-specific executive function training has been effective in other research and has the additional benefit of potential generalised gain across other health domains. For example, Klingberg et al. (17) found non-specific working memory training improved both working memory and nonverbal complex reasoning in children with ADHD. Furthermore, in previous research self-regulation interventions did not have to be domain-specific to be effective. For example, Oaten and Cheng (19) found a regular program of academic study improved a range of health and non-health behaviours. Therefore, further exploration and comparison of the relative benefits of specific and non-specific executive function training within the field of sleep hygiene is necessary.

Kor and Mullan (3) previously found response inhibition predicted a substantial proportion of variance in sleep hygiene. Combined, these findings seem to suggest that although GNG performance both predicts sleep hygiene and is malleable, changes in task

performance do not necessarily result in changes in response inhibition (and subsequently sleep hygiene), over and above the changes in self-regulation as a result of self-monitoring.

Limitations

There are some limitations to the current study which need to be considered. The current study was conducted over the internet, which may reduce the reliability of the response inhibition reaction times and questionnaire data as there was less control over the environment than may be found in lab-based settings. However, the GNG and Stroop have been successfully used in non-lab-based settings (3, 33, 40). Therefore, the value of executive function tasks should not be dismissed without further exploring their reliability and validity for assessment and intervention within applied and non-lab-based health psychology settings.

The contrast analyses were used to compare the combined experimental groups to the control group (hence testing the effectiveness of the self-monitoring training), and also to compare the two experimental groups (hence testing the incremental effectiveness of response inhibition training). Whilst this design enables the effects of self-monitoring to be explored, the possibility that the response inhibition training may be confounded with the self-monitoring training cannot be ruled out. Future research should consider using a 2x2 design with a response inhibition only group to test this alternative explanation.

High initial sleep hygiene levels may have created a ceiling effect, thus potentially reducing the effectiveness of both the experimental manipulations. Although previous samples of university students have had poor sleep hygiene, the current sample appeared to have reasonable sleep behaviours. Follow-up studies on individuals with poorer sleep hygiene are warranted. In addition, drop-out rates were not equal across groups, which may influence results, and further replication is therefore warranted. Finally, the majority of the sample was female, and may therefore the findings not be representative of males.

Implications and Future Directions

Given that many university students experience poor sleep, diaries provide a useful avenue for improving sleep hygiene in this population, and are likely to be cost effective as an intervention component as they are administered by the individual with little experimenter contact. Further research could test whether variations in diary length bring about changes in other sleep hygiene behaviours, as well as other health behaviours.

In addition, preliminary research has suggested that self-monitoring can alleviate anxiety and stress (19). As the diary in the current study specifically improved avoiding anxiety and stress provoking activity before bed, self-monitoring techniques may also be useful components for interventions targeting anxiety and stress in clinical and non-clinical settings, and should be further explored. In addition, although tension and stress have been previously found to be the strongest predictors of poor sleep quality (1), further research is needed to explore which specific aspects of sleep quality, sleep quantity, and sleep consistency improve as a result of changes to this, and other, sleep hygiene behaviours.

The paucity of research into sleep hygiene in healthy individuals makes comparison with previous research difficult, and therefore further research is needed to validate the current findings and determine the role of response inhibition in predicting and explaining sleep hygiene behaviour. In addition, whilst the current three sleep hygiene behaviours were the most relevant for the target population, they are by no means exhaustive, and in other populations other sleep hygiene behaviours may need to be investigated.

Finally, it appears that general response inhibition training is unlikely to be effective in improving sleep hygiene. This finding is interesting as it suggests that components of self-regulation trianing used in some other studies, but not used in this study, are likely to be active ingredients in such training, In addition to using behaviour-specific training as outlined above, training that increases in difficulty over time may also be important in improving health behaviours (17). Further research is needed to compare and contrast different forms of

self-regulation training and their effectiveness on a range of health behaviours, in order to determine the most effective form of such training for use in future interventions.

Conclusion

The current study suggests that some sleep hygiene behaviours such as avoiding stress and anxiety provoking activity before bed may be improved through self-monitoring practices such as keeping a sleep diary. Given the medium effect size, the extent to which diaries and other forms of self-monitoring can be effective in the field of health promotion warrants further attention, and may be a useful avenue for larger scale sleep behaviour intervention designs. Response inhibition training does not appear to improve sleep hygiene above the effects of the sleep diary, however behaviour-specific and incrementally improving manipulations need to be considered before executive function training is ruled out as an intervention strategy for sleep hygiene.

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