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RESEARCH REPORT

Placebo Sleep Affects Cognitive Functioning

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The placebo effect is any outcome that is not attributed to a specific treatment but rather to an individual's mindset (Benson & Friedman, 1996). This phenomenon can extend beyond its typical use in pharmaceutical drugs to involve aspects of everyday life, such as the effect of sleep on cognitive functioning. In 2 studies examining whether perceived sleep quality affects cognitive functioning, 164 participants reported their previous night's sleep quality. They were then randomly assigned to 1 of 2 sleep quality conditions or 2 control conditions. Those in the "above average" sleep quality condition were informed that they had spent 28.7% of their total sleep time in REM, whereas those in the "below average" sleep quality condition were informed that they had only spent 16.2% of their time in REM sleep. Assigned sleep quality but not self-reported sleep quality significantly predicted participants' scores on the Paced Auditory Serial Addition Test and Controlled Oral Word Association Task. Assigned sleep quality did not predict participants' scores on the Digit Span task, as expected, nor did it predict scores on the Symbol Digit Modalities Test, which was unexpected. The control conditions showed that the findings were not due to demand characteristics from the experimental protocol. These findings supported the hypothesis that mindset can influence cognitive states in both positive and negative directions, suggesting a means of controlling one's health and cognition.

Keywords: placebo, sleep, cognitive functioning

Placebos have figured into science and medicine since anesthesiologist Henry Knowles Beecher (1904–1976) reported watching soldiers benefit from a saline solution disguised as a strong pain reliever and later began researching the phenomenon (Bensing & Verheul, 2010). The placebo effect has since been defined as any outcome that is not attributed to a specific treatment but rather to an individual's mindset regarding the kind of treatment he or she is receiving (Benson & Friedman, 1996). Placebo information exerts its effect when an individual's belief that he or she has received treatment causes him or her to experience the outcome appropriate to the expected treatment.

Classical conditioning has been implicated as an underlying cause for the placebo's effectiveness (Benedetti & Amanzio, 2011). Proponents of the classical conditioning model have argued that a lifetime of medical treatments serve as conditioning trials to pair the medical context (conditioned stimulus) with therapeutic effects (conditioned response). An alternative view proposes that conscious expectancies mediate the changes associated with placebo effects. In this model, the internal expectancies associated with the inert treatment are responsible for an endogenous regulation of processes that produce the changes associated with placebo response (Bensing & Verheul, 2010).

Although most instances of the placebo effect have been related to pharmaceutical drugs, the phenomenon can also extend beyond the context of pain reduction to involve various aspects of everyday life. In recent years, placebo information has influenced outcomes as diverse as intoxication, weight loss, rash reaction to fake poison ivy, and altered neurochemical activity in Parkinson's disease (Atlas & Wager, 2009; Crum & Langer, 2007). These findings highlight the importance of perception and the brain's role in physical health. Furthermore, they hold implications for health care, suggesting that a physician's confidence or lack of confidence in a treatment could affect the treatment's outcome and, similarly, that a patient's attitude regarding his or her own treatment could serve to enhance or diminish the desired result.

Nontraditional explorations of the placebo effect within everyday activities have aided the understanding of the powerful psychological control people have over their physiology and health. Crum and Langer (2007), for instance, predicted that the health benefits of exercise might not arise solely from exercise. Their study found that over 1 month, a group of hotel maids, informed of their job's exercise benefits, showed a decrease in weight, blood pressure, body fat, waist-to-hip ratio, and body mass index compared with the control group. Crum, Corbin, Brownell, and Salovey (2011) found that when participants consumed a 380-calorie milkshake that they were told was an "indulgent" 620-calorie milkshake, they produced a significantly steeper decline in ghrelin,

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a gut peptide, than when they were told they had consumed the "sensible" 140-calorie milkshake. This influence on physiological states was further supported by Langer, Djikic, Pirson, Madenci, and Donohue (2010), who primed participants with the mindset that athletes have better vision than nonathletes. When arousal was controlled, greater visual acuity resulted from doing jumping jacks than from skipping, which was perceived to be a less athletic activity. Thus, the manipulation of a variety of mindsets, typically through the experimental manipulation of priming, appeared to impact physiology and counteract physiological limitations, depending on what participants believed to be true, not on any external manipulations.

Shiv, Carmon, and Ariely (2005) provided support for the mindset's influence on performance and further examined the expectancy process. They found that consumers who paid a discounted price for an energy drink thought to increase mental acuity were able to solve fewer puzzles than were consumers who purchased the same product at its regular price, demonstrating a price–efficacy connection. A second experiment revealed that drawing participants' attention to their beliefs about the price–efficacy connection weakened the effect, suggesting that the process by which expectations lead to the placebo effect occurs nonconsciously.

Ergogenic agents, such as energy drinks and coffee, are commonly expected to increase the capacity for bodily or mental labor by eliminating symptoms of fatigue or sleep inertia (Van Dongen et al., 2001). Pollo, Carlino, and Benedetti (2008) reported that placebo caffeine also produced this effect, finding a significant increase in muscle work after the administration of placebo caffeine. Similarly, Beedie, Stuart, Coleman, and Foad (2006) found that placebo caffeine enhanced performance in well-trained cyclists. Other studies support a consistent effect of caffeine expectation, revealing an improvement in vigilance and cognitive functioning (Fillmore, Mulvihill, & Vogel-Sprott, 1994). In studies of sleep–deprived people, Anderson and Horne (2008) found significantly fewer lapses and shorter reaction times on a psychomotor vigilance test following placebo caffeine, compared with the control group. Sun, Zhang, He, Liu, and Miao (2007) found that placebo caffeine exerted prolonged positive effects on both vigilance and cognitive performance during 28-hr sleep deprivation.

Symptoms of sleep deprivation, including a decline in cognitive functioning, are wide-ranging. Sleep deprivation has been shown to reduce attentional arousal, impair central processing, and lower cognitive functioning overall (Ratcliff & Donger, 2009). Both long-term sleep reduction and short-term sleep deprivation significantly increased distractibility and decreased logical reasoning and auditory vigilance (Blagrove, Alexander, & Horne, 1995). Sleep loss has also been linked to decreased verbal fluency (Harrison & Horne, 1997), decreased response times and accuracy on working memory tasks (Bartel, Offermeier, Smith, & Becker, 2004; Pilcher et al., 2007), and decreased performance times in mental arithmetic abilities (Frey, Badia, & Wright, 2004).

As the cognitive deficits resulting from sleep deprivation can be alleviated by the consumption of placebo caffeine, which exerts an expectancy effect (Sun et al., 2007), it follows that changing one's mindset or expectancy about one's sleep experience may also serve to alleviate the symptoms of decreased cognitive functioning. Changes in the mindsets associated with exercise, satiation, vision, and fatigue have already been shown to produce physiological changes, suggesting an ability to overcome physiological limits with psychological means. Thus, it follows that the decline in cognitive functioning associated with sleep deprivation or an improvement in cognitive functioning associated with high sleep quality may be due in part to the expectation of such effects and that these effects may be altered by changing the expectation. In the present study, we hypothesized that the participant's perception of his or her own sleep quality could be manipulated and that this would affect his or her cognitive functioning. It was hypothesized that participants would perform worse on a difficult test of attention and memory if they perceived themselves to have slept poorly the night before, regardless of their actual sleep quality.

Experiment 1

Method

Participants. Fifty undergraduate students ages 17–21 years ($M = 20$ years, $SD = 1$) participated in this study. Participants were 19 men and 31 women whose areas of study included natural science ($n = 20$), humanities ($n = 14$), and social science ($n = 8$); eight were undecided. Participants were recruited through the student electronic mailing list ($n = 25$) as well as through presentations to classes ($n = 6$) and student groups ($n = 19$). Participants were given $5 gift cards as compensation for their involvement.

Procedure. This study was approved by the institutional review board at Colorado College. All participants gave informed consent and then rated how deeply they had slept the night before, on a scale of 1–10, with 10 being very deeply. They were then randomly assigned to either an "above average" or a "below average" sleep quality condition.

Participants received a 5-min lesson on sleep quality and cognitive functioning, which was disguised as background information that would provide them with a greater understanding of their participation. Participants were informed that, on average, normal adults spend between 20% and 25% of their sleep time in REM sleep and that individuals who spend less than 20% of their time in REM sleep tend to perform worse on tests of learning and memory, whereas individuals who spend more than 25% of their time in REM sleep tend to perform better. They were then informed of a new technique whereby the previous night's percentage of REM sleep could be determined by measuring the lingering biological measurements of heart rate, pulse, and brainwave frequency the next day. The experimenter conceded that there had been considerable skepticism surrounding the new technique but that leading sleep specialists had correlated results from this technique with those of a polysomnogram, which had yielded a reliable relationship. Participants were informed that the reading for percentage of REM sleep was unaffected by extraneous factors, such as coffee consumption, alcohol consumption, or medication use.

Participants were then connected to BIOPAC equipment (BIOPAC Systems, 2000), which they were told would measure their pulse, heart rate, and brainwave frequency. Pulse and heart rate appeared to be measured; however, in reality, only brainwave frequency was measured such that participants could view their EEG readings for 5 min as the readings were being conducted. As participants removed the electrodes, they were told that their data were automatically downloading through a database and running through a preprogrammed equation. Participants then watched the experimenter calculate either 16.2% REM sleep (for the below average sleep quality condition) or 28.7% REM sleep (for the above average sleep quality condition) on a fake spreadsheet containing graphs and extensive charts of numbers. The experimenter then compared the readout for percentage of REM sleep with the participant's self-reported sleep quality, explaining that past research had shown little correlation between actual sleep quality and self-reported data. This was to diminish the participants' reliance on their own judgments of their sleep quality.

Participants were then administered the Paced Auditory Serial Addition Test (PASAT). After they completed the PASAT, participants were informed of the study's true purpose through debriefing.

Materials.

PASAT (Gronwall, 1977). The PASAT assesses auditory attention and speed of processing, skills most affected by sleep deprivation (Waters & Bucks, 2011). Participants listened to a tape that presented a series of single digit numbers at the rate of one every 1.6 s. Participants added the first two numbers and gave a verbal answer. When the next number was heard, they then added it to the number they had heard directly before, as opposed to the number they had just stated. Participants completed 10 practice items before beginning the task and 50 numbers were presented on the tape. The experimenter recorded the total number of correct responses out of 50. The PASAT has a test–retest reliability of r = .96 (Tombaugh, 2006), and it is a sensitive test perceived as difficult and stressful by healthy participants (Lezak, Howieson, Bigler, & Tranel, 2012); thus, it is unlikely to yield ceiling effects among undergraduate students.

Results

Participants' self-reported sleep quality and assigned sleep quality were the two predictors examined, while participants' scores on the PASAT constituted the dependent measure. Self-reported sleep quality was measured via the question, "On a scale of 1–10, how deeply do you feel that you slept?" Table 1 shows the means and standard deviations for both above average and below average assigned sleep quality groups and the age-appropriate PASAT norms (Spreen & Strauss, 1991). Figure 1 shows the PASAT means for the above average and below average assigned sleep quality groups. Table 2 provides a Pearson correlation matrix between assigned sleep quality, self-reported sleep quality, and participants' PASAT scores.

The data were analyzed via regression to best account for the continuous independent variable of self-reported sleep quality. An

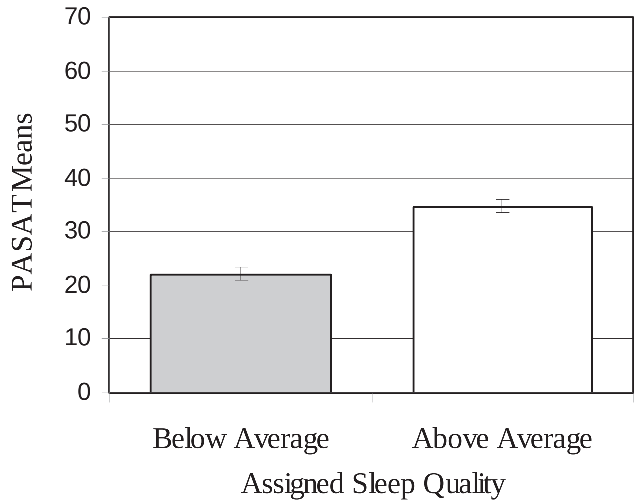

Figure 1. Means of the PASAT for the "below average" and "above average" assigned sleep quality conditions in Experiment 1. Error bars represent standard errors. PASAT = Paced Auditory Serial Addition Test.

interaction predictor was created, after centering the two original predictors at zero to ensure that the variables would be orthogonal, and then analyzed as a third predictor. A multiple regression using the predictors self-reported sleep quality, assigned sleep quality, and the interaction predictor significantly predicted performance on the PASAT, $F(3, 46) = 17.13$, $p < .001$, $R^2 = .53$. Specifically, assigned sleep quality significantly predicted cognitive functioning, $b = .73$, $t(49) = 7.17$, $p < .001$, whereas self-reported sleep quality did not predict cognitive functioning, $b = .033$, $t(49) = 0.33$, *ns*. The interaction between self-reported sleep quality and assigned sleep quality did not predict cognitive functioning, $b = .001$, $t(49) = 0.010$, *ns*.

The experimenter rated participants' beliefs in the manipulation by monitoring their reactions and questions throughout the experiment and to the debriefing. A majority of participants (88%) stated that they had completely believed the manipulation, with only six participants admitting minor skepticism, adding that they still did not question the validity of the information. Therefore, all participants' data were used in the analyses.

Table 1
Means and Standard Deviations of the PASAT for "Below Average" and "Above Average" Assigned Sleep Quality and Adult Norms for Experiments 1 and 2

Assigned sleep quality	Experiment 1		Experiment 2	
	M	*SD*	*M*	*SD*
Below average	22.13	6.35	26.19	6.48
Above average	34.81	5.92	32.24	8.43
Adult norms	36.00	13.00		

Note. PASAT = Paced Auditory Serial Addition Test.

Table 2
Correlations Between the Predictors and PASAT Scores for Experiments 1 and 2

Predictor	PASAT	1	2	3
Experiment 1				
1. Assigned sleep quality (ASQ)	.726**	—		
2. Self-reported sleep quality (SSQ)	.019	−.020	—	
3. ASQ × SSQ interaction	.004	.002	.049	—
Experiment 2				
1. ASQ	.378**	—		
2. SSQ	.026	.101	—	
3. ASQ × SSQ interaction	.004	−.002	−.093	—

Note. PASAT = Paced Auditory Serial Addition Test.
** $p < .005$.

Discussion

Experiment 1 supported the hypothesis that assigned sleep quality affects cognitive functioning. When participants were informed that they had experienced below average sleep quality the night before, they tended to perform worse on the PASAT, regardless of how well they originally felt they had slept. Those in the above average sleep quality condition performed within normal limits on the PASAT. The observed pattern of cognitive functioning is consistent with what one might observe if participants had actually experienced a poor night's sleep. Ratcliff and Donger (2009) found an overall decline in cognitive functioning and attentional arousal in sleep-deprived participants. Blagrove et al. (1995) found a decrease in auditory vigilance for short-term sleep deprived individuals. And Frey et al. (2004) found slower times in mental arithmetic. All of these effects are measured by the PASAT (Tombaugh, 2006).

One limitation of this experiment was that the experimenter was not blind to the participants' condition; thus, experimenter expectancies could have influenced the results. Although the likelihood of bias was reduced by the experimenter's scripts being constant and the PASAT being administered via a recording, it was still possible. In addition, it was unclear what role demand characteristics played in this experiment, even considering that much of the placebo effect relies on demand characteristics. It may have been possible that merely knowing that the study was assessing the link between sleep and cognitive functioning would have produced these results. The effect of assigned sleep quality on PASAT scores was strong; however, it was also left unclear how far this effect might generalize to other tests. Experiment 2 was conducted to attempt to replicate this experiment while eliminating potential experimenter bias, investigating demand characteristics, and expanding the dependent measures.

Experiment 2

Method

Participants. One hundred fourteen undergraduate students ages 18–23 years (M = 19.3 years, SD = 1.33) participated in this study. Participants were 43 men and 71 women whose areas of study included natural science (n = 40), humanities (n = 20), and social science (n = 29); 25 were undecided. Participants were recruited in student centers (n = 46) as well as through presentations to classes (n = 56) and student groups (n = 12). Participants were given $5 gift cards as compensation for their involvement.

Procedure. This study was a replication of Experiment 1 with the following revisions. First, two control conditions were added to account for demand characteristics. The first condition (n = 29) involved administering a nine-item daily habits questionnaire with the embedded question, "On a scale of 1–10, how deeply do you feel you slept last night?" Participants then completed the dependent measures. The second condition (n = 29) involved only administering the sleep quality question and then having participants complete the dependent measures. The other two conditions were replications of Experiment 1's above average (n = 29) and below average (n = 27) assigned sleep quality conditions. Participants in all conditions were initially told they would be participating in a study on "daily habits and cognition," but all participants except those in the first condition were subsequently told the experiment would be focusing on sleep quality.

The second revision was to use an experimenter unaware of the conditions to administer the dependent measures. The primary experimenter administered the daily habits or sleep quality questionnaire and manipulation (if given) in one room and then directed participants to a separate room where an experimenter unaware of the study's hypotheses administered the dependent measures.

The final revision was to include three additional dependent measures to determine whether the previously observed effect could be generalized. These dependent measures were the Controlled Oral Word Association Task (COWAT), the Symbol Digit Modalities Test (SDMT), and the Digit Span Task. This revised protocol was approved by the institutional review board at Colorado College.

Materials.

PASAT (Gronwall, 1977). The PASAT was administered as in Experiment 1.

COWAT (Benton & Hamsher, 1976). Verbal fluency, which is commonly affected by sleep loss (Waters & Bucks, 2011), was assessed by the COWAT. The COWAT has a test–retest reliability of .88 (DesRosiers & Kavanaugh, 1987). Participants were given 1 min to say as many words as possible beginning with a given letter (*F, A, S*). The total number of words produced for all three letters was then used as the outcome measure.

SDMT (Smith, 1995). Visual-motor processing speed, also consistently affected by sleep loss (Waters & Bucks, 2011), was assessed by the SDMT. The SDMT has a test–retest reliability of .80 (Smith, 1995). The SDMT involves a substitution task in which participants were asked to match a number, 1–9, to its corresponding symbol. Participants were given 90 s to complete as many of the 110 substitutions as possible, filling in each substitution in order. The total number of substitutions completed correctly was used as the outcome measure.

Digit Span task (Wechsler, 1981). Immediate auditory recall was assessed by an expanded version of the Digit Span test of the Wechsler Adult Intelligence Scale—Revised, which has a test–retest reliability of r = .89 (Wechsler, 1981). Most research does not show effects of sleep loss on digit recall (Waters & Bucks, 2011); therefore, this test was included to test the limits of the generalizability of the experimental effect. Participants were presented with a series of digits (e.g., "8, 3, 4") and were instructed to immediately repeat the digits back to the experimenter. After successful completion of at least one of two series of the same length, participants were then given a series longer by one digit (e.g., "9, 2, 5, 4"), with the range of digits being 3–13. The length of the longest list that a participant could remember was used as his or her outcome measure rather than scaled score to limit the restriction of range inherent in this test (Lezak et al., 2012).

Results

Participants' self-reported sleep quality and assigned sleep quality were the two predictors examined, and participants' scores on the PASAT, COWAT, SDMT and Digit Span constituted the dependent measures. Self-reported sleep quality was measured via the question, "On a scale of 1–10, how deeply do you feel that you slept?" Tables 1 and 3 show the means and standard deviations for

Table 3
Means and Standard Deviations of Dependent Measures for "Below Average" and "Above Average" Assigned Sleep Quality and Adult Norms for Experiment 2

Assigned sleep quality	COWAT		SDMT		Digit Span	
	M	*SD*	*M*	*SD*	*M*	*SD*
Below average	43.85	12.56	59.81	8.31	7.07	1.66
Above average	51.00	11.63	64.21	11.16	7.34	1.17
Adult norms	43.51	9.44	61.93	10.15	6.00	1.00

Note. COWAT = Controlled Oral Word Association Test; SDMT = Symbol Digit Modalities Test.

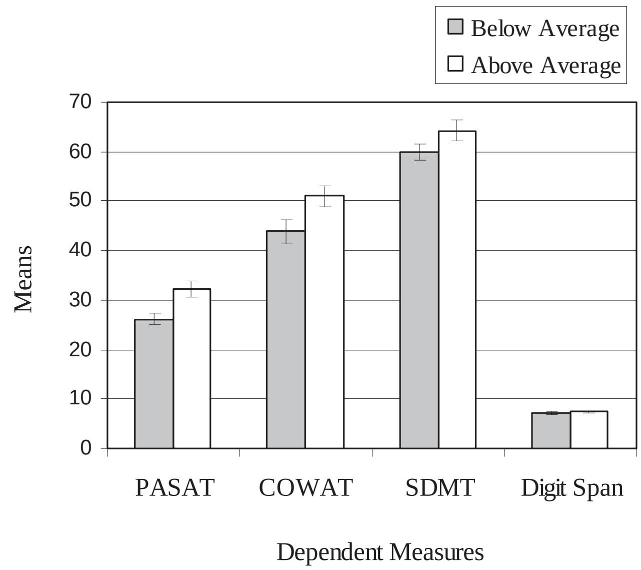

Figure 2. Means of the dependent measures for the "below average" and "above average" assigned sleep quality conditions in Experiment 2. Error bars represent standard errors. PASAT = Paced Auditory Serial Addition Test; COWAT = Controlled Oral Word Association Test; SDMT = Symbol Digit Modalities Test.

the above average and below average assigned sleep quality conditions and the age-appropriate PASAT, COWAT, SDMT, and Digit Span norms (Loonstra, Tarlow, & Sellers, 2001; Smith, 1995; Spitz, 1972), while Tables 2 and 4 provide a Pearson correlation matrix between assigned sleep quality; self-reported sleep quality; and participants' PASAT, COWAT, SDMT and Digit Span scores. The means are also displayed in Figure 2.

The data were analyzed via regression as in Experiment 1. A multiple regression using the predictors self-reported sleep quality, assigned sleep quality, and the interaction predictor significantly predicted performance on the PASAT, $F(3, 52) = 2.89$, $p < .04$, $R^2 = .14$. Specifically, assigned sleep quality significantly predicted cognitive functioning, $b = .38$, $t(54) = 2.94$, $p = .005$, whereas self-reported sleep quality did not predict cognitive functioning, $b = .01$, $t(54) = 0.09$, *ns*. The interaction between self-reported sleep quality and assigned sleep quality did not predict cognitive functioning, $b = .004$, $t(54) = 0.03$, *ns*.

A multiple regression using the predictors self-reported sleep quality, assigned sleep quality, and the interaction predictor significantly predicted performance on the COWAT, $F(3, 52) = 4.64$, $p = .006$, $R^2 = .21$. Specifically, assigned sleep quality significantly predicted cognitive functioning, $b = .27$, $t(54) = 2.15$, $p = .04$, whereas self-reported sleep quality did not predict cognitive functioning, $b = .21$, $t(54) = 1.68$, *ns*. The interaction between self-reported sleep quality and assigned sleep quality significantly predicted cognitive functioning, $b = .27$, $t(54) = 2.20$, $p = .03$. When parsed, there was no relationship between self-reported sleep quality and COWAT score in the above average group, $r(27) = -.07$, $p = .738$. However, in the below average group, there was a significant relationship between self-reported sleep quality and COWAT score, $r(25) = .52$, $p = .006$.

A multiple regression using the predictors self-reported sleep quality, assigned sleep quality, and the interaction predictor did not significantly predict performance on the SDMT, $F(3, 52) = 1.51$, $p = .22$, $R^2 = .03$, nor did it predict performance on the Digit Span, $F(3, 52) = 0.53$, $p = .66$, $R^2 = .03$.

A Pearson correlation was performed on the data from Condition 2 to assess the relationship between self-reported sleep quality and the dependent measures in those who were given demand characteristics that the study was about sleep and cognition but no manipulation of sleep quality information. There was no significant correlation between self-reported sleep quality and PASAT scores, $r(27) = .31$, $p = .11$; between self-reported sleep quality and COWAT scores, $r(27) = .33$, $p = .08$; between self-reported sleep quality and SDMT scores, $r(27) = .11$, $p = .56$; nor between self-reported sleep quality and Digit Span scores, $r(27) = .18$, $p = .36$. Table 5 provides a Pearson correlation matrix between self-reported sleep quality and participants' dependent measures for Condition 2. Although a comparison with Condition 1 (sleep

Table 4
Correlations Between the Predictors and Dependent Measures for Experiment 2

Predictor	COWAT	SDMT	Digit Span
Assigned sleep quality (ASQ)	.288**	.220	.096
Self-reported sleep quality (SSQ)	.262	.085	−.072
ASQ × SSQ interaction	−.292**	−.172	−.110

Note. COWAT = Controlled Oral Word Association Test; SDMT = Symbol Digit Modalities Test.
** $p < .05$.

Table 5
Correlations Between Self-Reported Sleep Quality and Dependent Measures for Conditions 1 and 2

Condition	PASAT	COWAT	SDMT	Digit Span
1: Self-reported sleep quality (when asked alone)	.31	.33	.11	.18
2: Self-reported sleep quality (when embedded in the daily habits questionnaire)	.17	.32	.09	.29

Note. PASAT = Paced Auditory Serial Addition Test; COWAT = Controlled Oral Word Association Test; SDMT = Symbol Digit Modalities Test.

quality question embedded in the daily habits questionnaire) was unnecessary, those correlation coefficients are provided in Table 5.

The experimenter rated participants' beliefs in the manipulation by monitoring their reactions and questions throughout the experiment and to the debriefing. A majority of participants (88%) stated that they had completely believed the manipulation, with only seven participants admitting minor skepticism, adding that they still did not question the validity of the information. Therefore, all participants' data were used in the analyses.

Discussion

Experiment 2 replicated the findings of Experiment 1 that assigned sleep quality affects cognitive functioning. When participants were informed that they had experienced below average sleep quality the night before, they tended to perform worse on the PASAT, regardless of how well they originally felt they had slept, and when they were informed that they had experienced above average sleep quality the night before, they tended to perform better on the COWAT, regardless of how well they originally felt they had slept. These findings did not extend to the Digit Span, which was expected, or to the SDMT, which was unexpected.

The observed pattern of cognitive functioning on the PASAT was again consistent with what one might observe if participants had actually experienced a poor night's sleep (Blagrove et al., 1995; Frye et al., 2004; Ratcliff & Donger, 2009; Waters & Bucks, 2011). The COWAT, however, revealed that it is possible to provide cognitive enhancement from verbal instruction on sleep quality, as the significant effect seemed to be driven largely from those in the above average group producing higher than normal scores. (The SDMT results sat largely in the center of these two findings, with the above average group above the adult norms and the below average group below the adult norms.) Several characteristics differentiate the COWAT from the PASAT, which may suggest an explanation. The COWAT is verbal (vs. numerical) and is simpler as it requires no testing materials; further, its responses are generated by the participant in an unrestricted fashion, giving the sense of more flexibility and perhaps control over the outcome. It is possible that one or more of these characteristics are related to the skills that would be enhanced by high-quality sleep. Indeed, Harrison and Horne (1999) found that sleep deprivation led to more rigid thinking and perseveration. It may follow that high-quality sleep is known to promote greater cognitive flexibility and this is what the above average participants demonstrated.

The COWAT results also revealed that self-reported sleep did not relate to COWAT scores the same way in both groups. There was no relationship between self-reported sleep and COWAT scores in the above average group, but there was a positive relationship between self-reported sleep and COWAT scores in the below average group. It is possible that the COWAT elicited a form of inoculation effect in the participants. That is, similar to the concept of stress inoculation, as participants in the below average group were administered an undesired persuasion, they might have been more likely to resist this manipulation, relying on their own beliefs more than those in the above average group did (Meichenbaum, 2007). Why inoculation might occur with the COWAT and not the PASAT, for instance, may again be related to the different characteristics of the two tests (e.g., verbal vs. numerical, simple vs. routinized administration, controllable vs. uncontrollable by the participant), or it may be that inoculation is more likely revealed in tests that are perceived as less difficult overall. That is, when given the below average manipulation and confronted with the PASAT, which is generally perceived as very difficult, it is likely that one might succumb to the manipulation and perform poorly, whereas, in contrast, it would be easier to resist the below average manipulation if the task allowed perceived successes, such as in the COWAT. Inoculation in the placebo effect would be quite interesting to explore in the future with a variety of manipulation strengths and perceived test difficulties.

In Experiment 2, we attempted to address demand characteristics directly by comparing the relationship between self-reported sleep quality and test scores in two groups: those who were asked only about their sleep (demand characteristics) and those who were asked about sleep among other daily habits. That self-reported sleep was not related to any of the dependent measures in either group suggests that demand characteristics (i.e., the participants knowing the variables of interest in the experiment) did not play a significant role in eliciting the effect.

General Discussion

In these experiments, cognitive functioning appeared to be mediated by placebo information, as it was dependent on the assigned sleep quality told to the participants as opposed to their actual self-reported sleep quality. These findings support earlier nontraditional placebo investigations that imply one's mindset is a determinant of physiological limits, such as those associated with exercise, vision, and satiation (Crum et al., 2011; Crum & Langer, 2007; Langer et al., 2010). These data support the generalization of this hypothesis to include the mindset's potential influence on the effects of sleep quality.

The mechanism by which mindset affects cognitive functioning is not yet fully understood; however, expectancy and classical conditioning are both likely contributors. It may be that expectancy directly creates the cognitive effects from perceived sleep quality or that they are mediated by increased anxiety or decreased motivation following information about poor sleep quality (or following actual sleep deprivation) or by increased motivation following information about high-quality sleep (or following actual high-quality sleep) (Stewart-Williams & Podd, 2004). Performance then becomes a self-fulfilling prophecy based on what is known by laypeople about the effects of actual sleep deprivation and restfulness. Classical conditioning, as seen in other placebo (or nocebo) effects, may also be at work (Stewart-Williams & Podd, 2004); that is, that the symptoms known from former episodes of poor- or high-quality sleep are evoked by perceived poor- or high-quality sleep.

It is possible that selecting those with known expectancies about the consequences of poor sleep quality and, even more so, prior experience with poor sleep quality would yield even higher predictive value from the manipulation, as actual prior experience (i.e., neurophysiological conditioning) has been shown under some circumstances to produce greater placebo effects than mere verbally mediated expectancies (Colloca et al., 2008). In addition, if the effects of sleep deprivation are more salient than the effects of high-quality sleep on attention, reaction time, and arithmetic, this might account for the direction of the results of the PASAT. If, in contrast, the effects of high-quality sleep are more salient than the effects of sleep deprivation on verbal fluency, then this might account for the direction of results of the COWAT. It appears that immediate auditory recall may be known to be unaffected by sleep, hence, the expected nonsignificant results from the Digit Span.

What is unknown are the common expectancies of sleep deprivation and high sleep quality among laypeople. Researchers conducting future studies should assess the expectancies of both sleep deprivation and high-quality sleep, similar to how alcohol researchers established the perceived consequences of alcohol ingestion among laypeople (e.g., Southwick, Steele, Marlatt, & Lindell, 1981). It would then be easier to hypothesize mapping the expectancy to the outcome.

In these experiments, we have shown that decrements in performance can be elicited when verbal instruction and technological displays convey poor sleep quality to the individual. We have also shown that increments in performance can be elicited when verbal instruction and technological displays convey high-quality sleep. Although the limits of this type of placebo effect should be explored and may be affected by the manipulations given and the tests administered, by understanding that one's mindset nonconsciously contributes to the existence of physiological and cognitive limits, an individual may then be able to consciously extend those limits, experiencing improved cognitive functioning, perhaps without even actually altering sleep patterns.

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