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THE EFFECT OF A DELAYED WEEKEND SLEEP PATTERN ON SLEEP AND MORNING FUNCTIONING

CHIEN-MING YANG[1,2,*] and ARTHUR J. SPIELMAN[1,3]

[1]*Sleep Disorders Center, The City College of The City University of New York*
[2]*Department of Psychology, Fu Jen Catholic University, 510 Chung Cheng Road, Hsinchuang, Taipei Hsien 24205, Taiwan*
[3]*Sleep Disorders Center, New York Methodist Hospital, Brooklyn, NY*

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It is a common practice for young adults to delay their weekend sleep schedule. The present study was designed to assess the effect of this sleep pattern on the sleep of Sunday night and the functioning of Monday morning. The sleep schedules of 30 young adults were manipulated for 2 consecutive weeks. In the Habitual-Sleep (HS) week, subjects followed their habitual sleep schedule throughout the week; in the Delayed-Sleep (DS) week, subjects' sleep schedule on Friday and Saturday nights were delayed by two hours. Compared to the HS week, subjects showed significantly lower subjective sleepiness near bedtime and trends of longer sleep onset latency on Sunday night in the DS week. In addition, there was both lowered cognitive performance and overall mood rating on Monday morning in the DS week. The delayed weekend sleep pattern contributes to Sunday night insomnia and the Monday morning "blues".

KEY WORDS: Sleep, sleep–wake schedule, insomnia, sleep hygiene, cognitive performance.

It is a common practice for young adults to stay up late and sleep late during the weekend. This sleep pattern has been shown to be associated with sleep disturbance, poor daytime functioning and lower mood status. A survey study showed that a subgroup of college students that reported a later to bed and later to rise schedule on weekends also reported a longer than average time to fall asleep of 42.7 minutes during the weekdays and poorer school performance compared to students with a more consistent weekend sleep schedule (Lack, 1986). Similarly, in high school students the delay in the weekend bedtime has been reported to be associated with poor academic performance (Allen, 1992; Kowalskik and Allen, 1995) as well as daytime sleepiness, depressive mood, and sleep/wake behavior problems (Wolfson and Carskadon, 1998).

It has been suggested that the mechanism responsible for the sleep disturbance and poor performance associated with the delayed weekend sleep pattern is a mild delay of endogenous circadian rhythms (Kowalskik and Allen, 1995; Valdez *et al.*, 1996). The endogenous circadian clock, that provides the internal coordination for parameters with near 24-hour periodicity, is normally synchronized by the environmental light–dark cycle. However, when the light–dark information and other time cues are absent, the intrinsic period length in humans averages slightly longer than 24 hours (Campbell *et al.*, 1993; Czeisler *et al.*,

* Corresponding author. Tel.: 886-2-29031111 ext. 2122; Fax: 886-2-29010171; E-mail: yang_cm@ yahoo.com.

1999). Therefore, there is an inherent tendency for circadian rhythms in general, and the sleep–wake rhythm in particular, to drift later in time.

In spite of its tendency to delay in time, the intrinsic circadian rhythm is normally synchronized by the exposure to light. A relationship between the timing of light exposure and the extent and direction of the circadian phase shift induced can be plotted as a Phase Response Curve (PRC). In general, light exposure in late subjective day and early subjective night produces a phase delay, and light exposure in late subjective night and early subjective day produce a phase advance (Minors *et al.*, 1991). Therefore, the later wake-up time, that is characteristic of the delayed weekend pattern, prevents exposure to morning light that can advance phase and reset the phase of the sleep–wake cycle to 24 hours. The resulting drift of the circadian rhythm produces a delay of circadian phase over the weekend. Sleep onset difficulties on Sunday and subsequent weekday nights as well as functional impairments on weekday mornings occur when the individual attempts to shift back to the regular weekday sleep schedule.

Previous studies examining the delayed weekend pattern have been survey and correlational studies, thus precluding causal inferences regarding the relationship between the delayed weekend sleep pattern and associated impairments (Allen, 1992; Kowalskik and Allen, 1995; Lack, 1986; Valdez *et al.*, 1996). Other factors may have contributed to both the sleep pattern and the sleep and performance problems. For example, a student who frequently goes to parties would go to sleep late during the weekend and might pay less attention to school work and thus not perform well academically. In fact, weekend party time and alcohol consumption in high school students have also been shown to correlate with the degree of the sleep delay during the weekend (Allen, 1992; Kowalskik and Allen, 1995). Therefore, to address the direct impact of the delayed weekend sleep pattern on sleep and daytime functioning, an experimental study in which the sleep pattern is directly manipulated is needed. Previous experimental studies have reported decrements in sleep, mood, and daytime performance following acute phase shifts of sleep–wake scheduled (Taub and Berger, 1973, 1974). However, to our knowledge, none have focused on the sleep and daytime functioning after a return to a habitual sleep schedule following a mildly delayed sleep schedule.

To better understand the impact of a delayed weekend sleep pattern, we conducted a field experiment using a within-subject, counterbalanced design in which subjects' sleep–wake schedule at home was manipulated with and without a delay during the weekend. We hypothesized that: (a) subjects would be less sleepy and take longer to fall asleep on the Sunday night following the delayed weekend sleep pattern; and (b) subjects would be sleepier, with both poorer mood and performance on the Monday morning following the delayed schedule.

METHOD

Subjects

Subjects were recruited from college campus settings with flyers. Potential subjects completed a medical and sleep history survey and were interviewed by an experimenter to determine their qualification for participation. Inclusion criteria were: (a) 18–35 years old; (b) with a regular sleep–wake schedule and not working shifts; (c) non-smoker; and (d) without a history of, and not currently troubled by, a sleep disorder, major medical illness, neurological or psychiatric disorder.

Forty-six (9 males and 37 females) subjects were initially included in the study. Sixteen discontinued due to either difficulty in following the designated sleep–wake schedule, failing to call in to report their schedule, or dropping out for unknown reasons. Most of the drop-outs discontinued during the pre-experimental week before the formal experimental week started. Thirty subjects (5 males and 25 females), between the ages of 18 and 31 (mean age = 22.3 years), completed the study. According to a daily sleep log filled out for one week during baseline, average weekday sleep–wake schedule was 11:31 p.m.–7:21 a.m. with an average time in bed (TIB) of 7.8 (SD = 1.0) hours. The average weekend sleep–wake schedule was 12:14 a.m.–9:04 a.m. with an average TIB of 8.8 (SD = 1.1) hours. Therefore, these individuals habitually delayed their sleep on the weekends and spent more time in bed.

Procedures

A sleep–wake schedule for the study was designated for each subject according to his or her reported habitual bedtime and wake-up time during weekdays. For subjects whose sleep–wake schedule varied day to day due to job or school schedule, the earliest wake-up time required was designated the wake-up time while the time in bed was set to approximate the habitual sleep period. However, the designated time in bed were set no shorter than 7 hours and no longer than 9 hours. The average designated bedtime was 11:21 p.m. and the average wake up time was 7:11 a.m., with an averaged TIB of 7.8 (SD = 0.7) hours. This approximated the habitual weekday schedule and was called the designated sleep–wake schedule.

The study was a field experiment in which all the experimental procedures were conducted in subjects' home environment. Throughout the period of the study, subjects were asked to refrain from drinking alcohol and taking naps. Caffeine consumption was limited to one cup or can of caffeinated drink per day before noon. To enhance the subjects' reliability in following the designated procedures, subjects were provided with a detailed checklist to follow. Also, subjects were called by an experimenter at least 3 times a week to remind them of the experimental procedures and to answer questions. In order to keep track of their sleep–wake schedule, they were required to keep sleep logs and to call into an automatic time-stamped voice mail system everyday right before going to bed and right after waking up.

The experiment consisted of one pre-experimental week and two experimental weeks. During the pre-experimental week, subjects followed their designated sleep–wake schedule everyday to stabilize their sleep–wake cycle. The two experimental weeks were comprised of one habitual-sleep (HS) week and one delayed-sleep (DS) week. The sequence of the two conditions was counterbalanced across subjects. Throughout the HS weekdays and weekend, subjects followed their designated sleep–wake schedules. During the weekdays of the DS week, the designated sleep–wake schedule was also followed. On Friday and Saturday of the DS week, bedtime and wake-up time were delayed (that is, set later) by two hours to simulate the delayed weekend sleep pattern. The two-hour delay was chosen to approximate the amount of bedtime delay in high school and college students reported in previous works (Allen, 1989; Kowalski and Allen, 1995; Lack, 1986).

On Sunday night of the DS week, the designated sleep schedule was followed, and subjects were asked to rate their sleepiness level with the Stanford Sleepiness Scale (SSS; see Measurements section) at five points in time: three hours, two hours, one hour, and 30 minutes before bedtime and right before going to bed. They were also asked to complete a visual analog mood scale (VAMS; see Measurements section) before going to bed. On Monday morning, subjects filled out a VAMS right after waking up and rated their sleepiness with the

SSS at five points in time: at awakening and at 30 minutes, one hour, two hours, and three hours after wake-up-time. In addition, an experimenter called the subjects on the telephone around 5 minutes after waking up for the administration of a Word List Memory Test (WLMT; see Measurements section) and a Control Oral Word Association test (COWA; see Measurements section). Subjects were asked to make sure the environment was not noisy or distracting before the test administration started.

Measurements

Sleep log. The sleep log consists of 16 questions divided into two parts: one part to be filled out before going to bed and the other to be filled out right after waking up. The evening portion was comprised of questions regarding the activities of the day, such as caffeine consumption, medications taken, exercise, and a 7-point rating on how difficult it was to wake up. The morning portion of the log asked questions about the sleep of the previous night, such as lights-out time, sleep onset latency, time out of bed in the morning, and a 7-point rating on sleep quality.

Stanford sleepiness scale (SSS). The SSS is a 7-point rating scale in which higher points on the scale describe an increasing level of sleepiness (Hoddes *et al*., 1973). Subjects were instructed to circle one of seven numbered statements that best described their level of alertness or sleepiness (e.g. from "1–feeling active, vital, alert, wild awake" to "7–almost in reverie, cannot stay awake, sleep onset appears imminent"). Rating on the scale has been shown to be elevated by one night of sleep deprivation and to return to the baseline after a recovery night (Hoddes *et al*., 1973).

Visual analog mood scale (VAMS). VAMS is a subjective rating scale for mood status. It required subjects to indicate their mood on 12 separate mood-related descriptions (e.g. "active", "tense", "sad", "happy") by making a vertical mark on a 100 mm horizontal line with two poles labeled "very little" and "very much". The length from the left end of the horizontal line to the point of the mark was measured in millimeters (mm) as the score for each item.

Cognitive tests. The selection of cognitive measures on Monday morning was limited by the feasibility of administration by phone and the time constraint (i.e. subjects needed to leave their homes for school or work soon after they woke up on Monday morning). A word list memory test (WLMT) and the Controlled Oral Word Association test (COWA; see Lezak, 1995) were chosen for the study. Two equivalent forms of each test were used for the two conditions in counterbalanced orders.

The WLMT consists of a free recall trial of 24 words. The word lists were taken from alternative forms of the Buschke Selective Reminding Test (see Spreen and Strauss, 1998). The words were read by the experimenter at a rate of approximately one word per 2 seconds. Subjects were asked to recall as many words as they could immediately after the list was presented. One night of sleep deprivation produces impairment of word-list free recall (Williams *et al*., 1966). The COWA test consists of two word-naming trials. Subjects were given one minute to generate as many words as possible that begin with a given letter of the alphabet, excluding proper nouns, numbers, and the same word with a different suffix. The number of words generated was the score. It has been demonstrated that 32 hours of sleep deprivation leads to poor performance on a similar test (Horne, 1988).

RESULTS

Dependent sample *t*-tests comparing the two conditions were performed on all the measures. Effect-size (*d*) was also calculated[12]. In addition, MANOVAs were conducted for VAMS data by including sleepiness related items only (i.e. "sleepy" and "alert") and emotion related items only (i.e. "sad", "happy", "irritable", and "angry").

Because of misunderstanding of the instructions or experimenter errors, there were missing data as follows: SSS ratings from one subject, Monday morning VAMS from three subjects, Sunday night VAMS from two subjects, sleep logs from three subjects, and cognitive tests from one subject. These subjects were not included for analysis on the particular measures of which they have missing data. However, their data on the other measures were included for the analysis.

Sunday Night

On Sunday night in the DS condition, subjects rated themselves significantly less sleepy on the SSS compared with the HS condition at 30 minutes before bedtime ($M=3.1$ [$SD=1.5$] and $M=3.7$ [$SD=1.3$], respectively, $t(28)=-2.10$, $p<.05$, $d=0.55$) and right at bedtime ($M=3.6$ [$SD=1.8$] and $M=4.3$ [$SD=1.6$], respectively, $t(28)=-2.31$, $p<.05$, $d=0.61$), with medium effect-sizes. There were no significant SSS differences between the two conditions three, two and one hour before bedtime (see Figure 1). VAMS ratings at bedtime are presented on Table 1. The results showed reductions in sleepiness in the DS condition

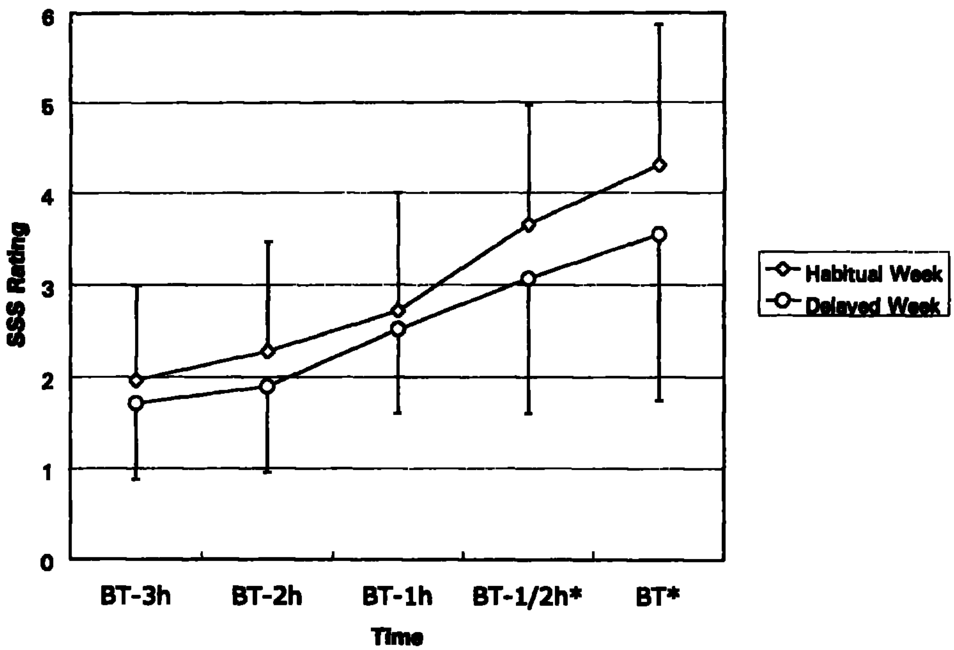

Figure 1 Means ($\pm SD$) of Stanford Sleepiness Scale (SSS) ratings from 3 hours before bedtime (BT) to bedtime on Sunday night: comparisons between Habitual-sleep and Delayed-sleep conditions ($N=29$). As indicated, subjects rated themselves less sleepy at half hour before bedtime and right at bedtime on Sunday night of the Delayed-sleep week compared with the ratings during the Habitual-sleep week. *$p<.05$.

Table 1 Visual analog mood scale ratings on Sunday night: comparison between Habitual and Delayed sleep conditions ($N = 28$)

Item	*Habitual*		*Delayed*				*Effect-Size*
	Mean	*SD*	*Mean*	*SD*	*F*	*p*	*d*
Alert	45.1	23.4	46.8	28.6	0.08	.78	0.07
Sad	25.4	25.8	16.1	17.9	2.55	.12	0.43
Tense	25.1	23.4	21.1	20.9	0.84	.37	0.25
Effort	42.2	26.9	35.1	27.7	1.45	.24	0.32
Happy	43.9	23	49.1	26.6	0.57	.46	0.22
Hungry	25.6	26.5	23.8	24	0.09	.77	0.08
Weary	48.7	29.2	43.6	30.9	0.61	.44	0.21
Irritable	33.2	28.2	27.9	28.8	0.67	.42	0.22
Sleepy	63.9	25.2	48	30.6	5.15*	.03	0.61
Angry	25.4	28.7	21.3	25.4	0.76	.39	0.23
Sexual	23.6	21.4	24.1	21.6	0.01	.91	0.04
Overall	55.3	19.5	57.2	25	0.12	.73	0.09

*$p < .05$.

Table 2 Sleep log measures on Sunday night: comparison between Habitual and Delayed sleep conditions ($N = 27$)

Variable	*Habitual*		*Delayed*				*Effect-Size*
	Mean	*SD*	*Mean*	*SD*	*t*	*p*	*d*
SOL	13.0	15.9	19.7	28.0	1.81	.08	0.60
WASO	1.1	2.0	0.7	1.3	−1.33	.20	0.33
TBT	476.7	37.5	474.4	38.1	−0.66	.52	0.18
TST	465.7	39.4	454.0	44.1	−1.78	.09	0.68
SQ	5.6	1.2	5.6	1.1	0.00	1.00	0.00
DW	3.3	1.4	3.4	1.5	0.14	.89	0.10

Note: SOL = sleep onset latency (min); WASO = wake time after sleep onset (min); TBT = total time in bed (min); TST = total sleep time (min); SQ = subjective rating of sleep quality; DW = subjective rating of difficulty waking up in the morning.

compared to the HS condition with medium effect-size. MANOVAs showed a significant difference between the two conditions with sleepiness related items ($F(2, 26) = 3.43$, $p < .05$), but showed no significant difference with emotion related items only ($F(4, 24) = .81$, n.s.).

None of the subjective sleep parameters on Sunday night were different between the two conditions (Table 2). However, there were near significant trends of longer sleep onset latency (SOL) with a medium effect-size (DS: $M = 19.7$ [$SD = 28.0$] min and HS: $M = 13.0$ [$SD = 15.9$] min, $t(26) = 1.81$, $p = .08$, $d = 0.50$) and shorter total sleep time (TST) with almost the same effect-size (DS: $M = 454.0$ [$SD = 44.1$] min and HS: $M = 465.7$ [$SD = 39.4$] min, $t(26) = 1.78$, $p = .09$, $d = 0.49$) in the DS condition compared to the HS condition.

Monday Morning

On Monday morning subjects generated significantly more words on the COWA in the HS condition ($M = 21.9$ [$SD = 7.1$] words) than in the DS condition ($M = 18.1$ [$SD = 6.3$] words) with a large effect size ($t(28) = -3.49$, $p < .005$, $d = 0.92$). On the WLMT, subjects memor-

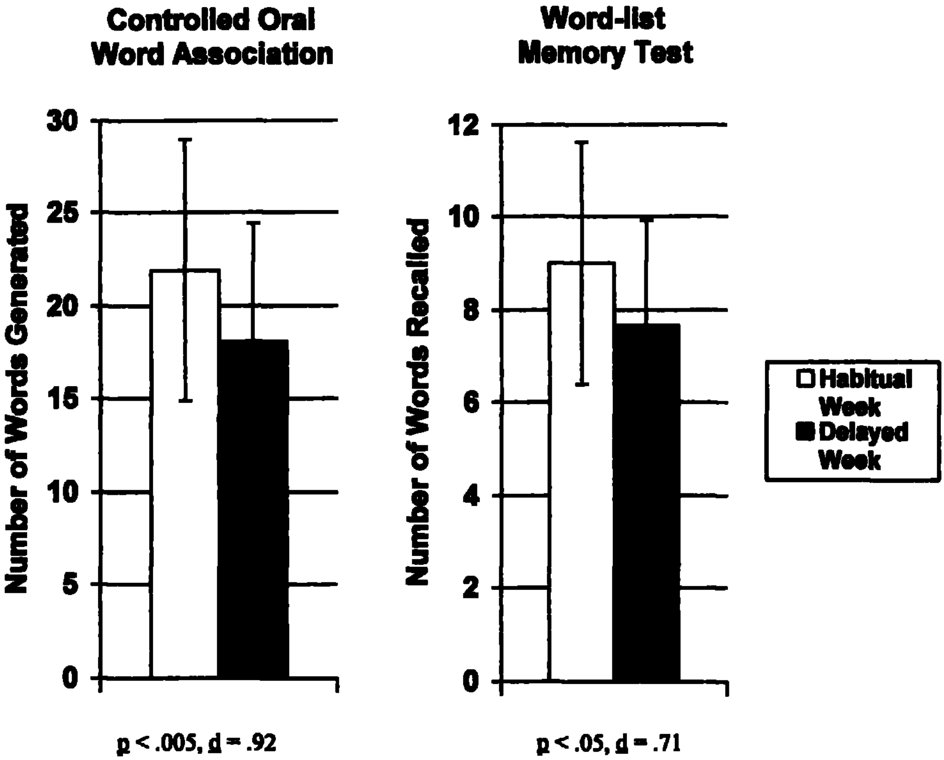

Figure 2 Cognitive performance (Mean ± *SD*) on Monday morning: comparisons between Habitual-sleep and Delayed-sleep conditions ($N = 29$). Subjects performed significantly better during Habitual-sleep condition for both the number of words generated on the Controlled Oral Word Association and the number of words recalled on the Word list Memory Test.

ized significantly more words in the HS condition ($M = 9.0$ [$SD = 2.6$] words) than in the DS condition ($M = 7.7$ [$SD = 2.3$] words) with a medium effect size ($t(28) = -2.71, p < .05, d = 0.71$) (see Figure 2).

On the mood scale on Monday morning, subjects rated themselves significantly less "alert", more "sleepy", more "irritable", more "angry", and overall in a worse mood following the DS weekend compared to the HS weekend, with medium to large effect-sizes (see Table 3). MANOVA results showed a significant difference with sleepiness related items ($F(2, 26) = 5.11, p < .05$) and no difference with emotion related items ($F(4, 24) = 1.96$, n.s.). In contrast, sleepiness ratings on the SSS on Monday morning were not different between the two conditions (see Figure 3).

DISCUSSION

This field study has shown that an imposed two-hour delay in bedtime and wake-up time on Friday and Saturday nights is followed by decreased subjective sleepiness and near-significant prolonged subjective time to fall asleep on Sunday night as well as significantly decreased mood and cognitive functioning on Monday morning.

Table 3 Visual analog mood scale ratings on Monday morning: comparison between Habitual and Delayed sleep conditions ($N = 28$)

Item	*Habitual*		*Delayed*				*Effect-Size*
	Mean	*SD*	*Mean*	*SD*	*F*	*p*	*d*
Alert	49.0	24.7	35.0	18.3	6.18*	.02	0.66
Sad	15.0	19.4	19.6	18.8	1.02	.32	0.27
Tense	29.1	24.4	34.2	22.0	0.69	.41	0.22
Effort	57.8	24.9	44.6	26.8	3.89	.06	0.53
Happy	44.6	25.5	37.4	18.9	1.49	.23	0.33
Hungry	38.1	30.6	34.6	26.3	0.23	.63	0.13
Weary	41.0	31.8	49.4	25.5	1.90	.18	0.37
Irritable	30.7	30.5	46.0	29.0	7.57*	.01	0.73
Sleepy	47.3	29.2	68.0	21.2	10.59***	.00	0.87
Angry	18.6	21.0	30.3	26.0	4.88*	.04	0.60
Sexual	17.8	19.1	17.0	18.8	0.08	.78	0.07
Overall	59.7	23.6	44.5	18.4	7.74*	.01	0.74

*$p < .05$; ***$p < .005$.

Although there was only a statistical trend for increased time to fall asleep on Sunday night following the delayed sleep pattern, four of the subjects reported substantial increases of SOL of more than 30 minutes to a clinically significant level (45–120 minutes). These findings suggest that this maladaptive sleep pattern may lead to transient sleep onset insomnia in some but not all individuals. In addition, the lack of a substantial increase in SOL in the DS condition on Sunday night may be due to chronic mild sleep deprivation or

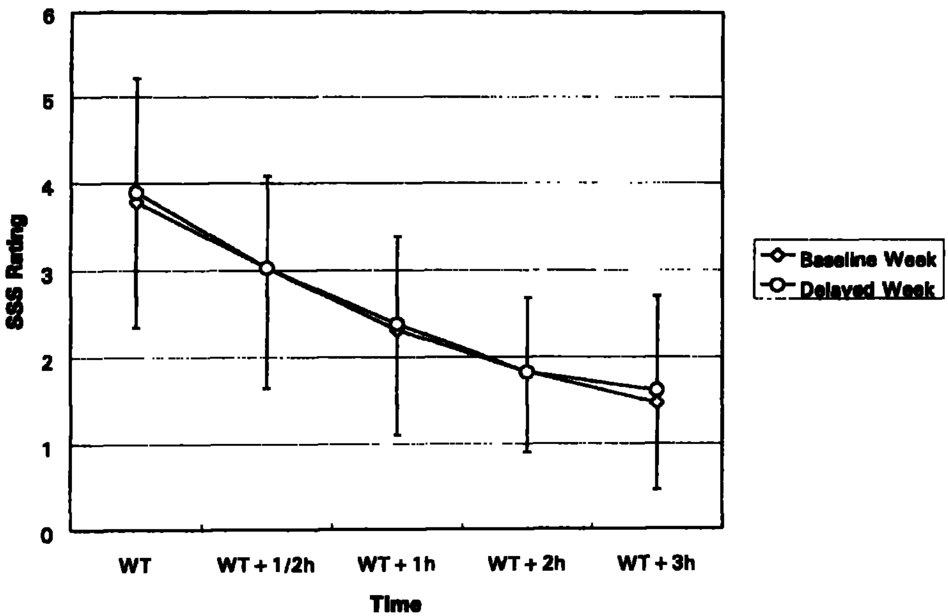

Figure 3 Means (± *SD*) of Stanford Sleepiness Scale (SSS) ratings from wake-up time to 3 hours after wake-up time on Monday morning: comparison between Habitual-sleep and Delayed-sleep conditions ($N = 29$). There were no significant differences between the ratings of the two conditions at any points of time.
(WT = wake-up time)

the imposition of a slightly restricted sleep schedule over the weekend. If our subjects, like most people, do not schedule enough time for sleep, they may easily fall asleep whenever given the opportunity (Johnson, 1998; Strauch and Meier, 1988). In this study, the average amount of time in bed was set at 7.8 hours, which matches their baseline weekday schedule but is one hour less than on their typical weekend.

The decreased sleepiness before bedtime in the DS condition may be explained by the delay in circadian rhythms on the delayed weekend schedule. The increased alertness in the evening may be due to a phase delay in the wake promoting rhythm. Therefore, on Sunday night in the DS condition, alertness may still be maintained instead of the slow decline in alertness prior to typical bedtime.

The impaired cognitive performance and mood ratings on Monday morning indicate that the delayed weekend sleep pattern can lead to decrements in immediate memory, verbal fluency, and mood status. These results are consistent with the decreased morning alertness and lowered academic performance associated with the delayed weekend sleep pattern reported in previous survey studies (Allen, 1992; Kowalskik and Allen, 1995; Lack, 1986; Wolfson and Carskadon, 1998). However, the SSS ratings on Monday morning were inconsistent with the sleepiness ratings on VAMS and showed no significant difference between the two conditions. One possible reason for this inconsistency is that the 7-point scale of SSS is not as sensitive as the visual analog scale used by VAMS. Since our subjects, as discussed above, may be mildly sleep deprived, the minor differences in morning sleepiness may be easily masked by morning activities (e.g. taking a shower, eating breakfast) and cannot be detected by less sensitive measures. Also, since the measures were obtained shortly after waking up, the effects may have been confounded by sleep inertia.

Although the current findings suggest that a phase delay in circadian rhythms may account for the impacts of the delayed weekend sleep pattern, a model of homeostatic regulation of sleep propensity offers a plausible alternative explanation (Borbely and Achermann, 1992). The homeostatic principle that the longer the prior wakefulness, the greater the sleep propensity may explain the decreased sleepiness on Sunday night in the DS condition. The late wake-up time Sunday morning in the DS condition shortens the duration of waking on Sunday. Similarly, the effect on mood and cognitive functioning on Monday morning may in turn be caused by the marginally poorer sleep on Sunday night in the DS condition. In order to differentiate the alternative hypotheses, measures of circadian rhythmicity, such as core body temperature or melatonin onset (Lewy and Sack, 1989) are needed to establish that a phase shift is responsible for the deficit seen. In addition, the observed effects may result from merely a "change" instead of a "delay" of sleep–wake schedule. The acute change of sleep–wake schedule may have aroused the subjects, and therefore decrease their sleepiness on Sunday night. Although it is less likely to lead to a decrease of morning functioning on Monday, future study by installing another group of subjects with earlier sleep–wake time may be required to verify this hypothesis.

A number of limitations of the study deserve mention. One limitation is the high dropout rate (35%) of the subjects. Most of the dropout subjects failed to follow a consistent sleep–wake schedule for a week. These subjects may represent a specific group of individuals who have more difficulty in controlling their sleep–wake pattern. They may indeed be more prone to the delayed weekend sleep pattern, although examination of their reported sleep–wake pattern revealed no differences from the subjects who completed the study.

Also, the subjects delayed their sleep schedule following the request of the experimenter. The effect may not be the same as the delayed weekend sleep pattern observed in natural settings when they choose to delay their sleep–wake schedule. However, the current findings are in the same direction as the results of previous survey studies in natural settings, indicating that the two types of delay generate similar results.

A potential design problem of the current study is that the subjects were not blinded to the manipulation of their sleep–wake schedule. Therefore, subjects' expectation could have contributed to the results obtained. However, expectation effects are not straightforward. While subjects may have known that a set bedtime and wake-up time promote good sleep, they may also have expected sleep disruption and performance decrements in the weekend of the HS condition because their typical sleep pattern was not permitted. Another methodological limitation due to the nature of field study is the lack of direct control over the subjects' sleep–wake schedule and daytime behaviors. However, some control was obtained by requiring subjects to call in immediately before going to bed and after waking up. In addition, the predominance of female subjects limits the generalizability of the results.

In conclusion, the current findings suggest that the common practice of going to bed late and getting up late during the weekend may lead to a transient mild "Sunday night insomnia", at least in some individuals. In addition, cognitive impairments as part of the "Monday morning blues" may interfere with school or job performance. This delayed weekend schedule may set the stage for the development of chronic sleep problems in the future. Individuals who delay their sleep schedules on the weekends may see themselves as having recurrent sleep problems and establish an identity as an insomniac. Such a self-perception may produce increased concern about sleep and become part of a self-fulfilling prophecy (see Kales *et al.*, 1976; Morin, 1993). Future studies should address strategies to limit the impact of the delayed weekend sleep pattern when it cannot be avoided due to social or work demands.

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