Adjustment of the Sleep–Wake Cycle to Small (1–2 h) Changes in Schedule

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Abstract

Changes of schedules larger than 3 h, such as jet lag and shift work, require an adjustment period of several days to resynchronize the sleep-wake cycle and several weeks to resynchronize other circadian rhythms to the new schedule. Initial studies on adaptation to small changes of schedule (1–2 h) found that the sleep-wake cycle adapts to the new schedule in less than 48 h, and such modifications are generally not studied because they may be confounded by a potential masking effect. This article summarizes the few published studies on Daylight Saving Time (DST) and sleep during weekends, two examples of small changes in schedule. There are individual differences in adaptation to daylight saving time, while some persons adjust immediately; other persons require more than 2 weeks. During weekends, people tend to go to bed and wake up later, and to extend their sleep. Delay and extension of sleep depend on factors such as shift of work during weekdays and chronotype (morningness–eveningness). Both DST and sleep during weekends offer the opportunity to study adaptation of the sleep-wake cycle in recurrent, social conditions. Studying these phenomena is also relevant to some socioeconomic issues, like the reported increase of traffic accidents and complaints from the population during daylight saving time; or the possible decrease in productivity and absenteeism during the ‘Blue Monday’.

Keywords: Sleep-wake cycle, human circadian rhythms, daylight saving time, weekends.

Introduction

Changes of schedule require an adjustment period that depends on several factors, such as shift duration, direction of the shift and the physiological or behavioral variable under study. Larger shifts are associated with greater adjustment periods, shifts...
that advance the clock are associated with longer adaptation periods than delay shifts, and sleep-wake cycle adjusts faster than body temperature or glandular secretion of different hormones. Resynchronization of human circadian rhythms has been studied both experimentally and in socially induced conditions, such as jet lag (Arendt & Marks, 1982) and shift work (Åkerstedt & Froberg, 1981). The majority of these studies involve shifts larger than 3 h. Shifts of one or two hours are commonly associated with only one or two days adjustment period (Toutou et al., 1990), so it seems that there is no effect on the circadian system and that this adjustment period is only part of a masking effect. Changing the schedule in a laboratory is different from changing the schedule in natural social conditions. In the laboratory the person is exposed to a new schedule of activities, with a new light-dark cycle or a self-selected light-dark cycle that is in accordance with the new timing. In social conditions the clock is modified but the natural solar light-dark cycle remains synchronized to the previous schedule, so that the person is now exposed to two conflicting Zeitgebers: the light-dark cycle that follows the previous schedule and the work activities that follow the new schedule. The objective of this work is to review the scarce available data on Daylight Saving Time (DST) and weekend delay, two examples of small (1–2 h) changes in schedule in social conditions. It is important to emphasize that a large proportion of the population is exposed to these conditions.

**Daylight Saving Time**

DST means advancing one hour in Spring and Summer from the standard time in Autumn and Winter. It was originally introduced in Germany in 1916, and it is now widely applied all around the world because of the resulting savings in electricity. Since the first time DST was introduced there have been complaints from the population. These have included reports of sleep disorders, difficulties adjusting to the new schedule, and concerns about safety of their children when they travel to the school in the morning while it is still dark (Bartky & Harrison, 1979).

Adjustment to DST involves three types of changes: changes in sleep duration, in social habits and in the sleep-wake cycle (Valdez et al., 2002). A transitory change in sleep duration (one night sleep deprivation) can occur during DST introduction, if people do not go to bed early according to the new schedule, effects will last only 1 or 2 days. Changes in social habits will mean benefits or problems to adjustment. For example, with DST introduction, people can dedicate some extra time in the evening to recreational activities, but some of these activities such as prolonged social meetings or extreme exercise, can interfere with sleep in some persons. Sleep-wake cycle can take several days or weeks to adjust to a new schedule because of the presence of two conflicting Zeitgebers, work schedule synchronized to DST and solar light-dark cycle synchronized to standard time. In contrast, returning to standard time in Autumn is not likely to produce sleep deprivation, because at that time people have to wake up and go to work 1 h later. At this transition, no specific change is expected in social habits, and a very fast and easy adjustment in the sleep-wake cycle is pre-
dicted because of the tendency of the human circadian system to oscillate with a period that is longer than 24 h.

Monk & Folkard (1976) studied 65 persons (55 female) during the transition from British Summer Time to Greenwich Mean Time in Autumn (phase delay). Subjects were recorded 6 days before and 11 days after changing the hour. Since there was a 1-h delay at such time transition, subjects 'gained' one extra hour in the morning. In that condition they still woke up approximately 20 min earlier for 1–2 days after changing the clock. Waking up times required a total of 5 days to become synchronized to the new clock hour. Subjective alertness, measured at 09:00 h, correlated positively with the length of time awake, and increased during the week following time transition. Oral temperature, measured at 09:00 h, showed a tendency to remain synchronized to the old time 6 days after changing the clock. The results of this study offer evidence that adjustment to daylight saving time elimination is not immediate, and it requires at least 5 days to attain the new phase. According to the data, transition to standard time does not mean special problems to the population, persons wake up earlier than normal, so that they have extra time to do their habitual activities (going to work, going to school, preparing meals, etc.).

Monk and Aplin (1980) studied DST over a 2-year span, both at Spring and Autumn, in 101 persons from two British cities (Brighton and London). They found an immediate adjustment of bedtime, both at Spring and Autumn transitions. Waking time required one week to adjust to DST, both at Spring and Autumn, during which subjects woke up 5–45 minutes later than normal. They also used alarm clocks more frequently. This study provide some support for a one week adjustment period to DST, with a sleep deprivation effect, as well as a sleep-wake cycle effect.

Nicholson and Stone (1978) studied the effects of British Summer Time introduction (phase advance) on the sleep architecture of three young adult males. Subjects were recorded 2 days preceding the change and 3 days after the change. They found that sleep latency increased from 17.3 min to 27.0 min, stage 4 increased from 25.9 min to 42.7 min, and awake time during sleep decreased from 55.6 min to 31.7 min. The results of this study imply that sleep architecture requires several days to adjust to daylight saving time introduction. The increase in Stage 4 and the reduction of waking activity during sleep are two possible consequences of sleep deprivation.

Valdez et al. (1991) studied the sleep-wake cycle of 19 workers during 28 days, 9 days before and 19 days after DST. There were individual differences in the time course of the adaptation to DST, 12 workers adjusted in 1 or 2 days, while the other 7 workers required more than 2 weeks to adjust. Criteria for adjustment was a significant deviation (exceeding 99% confidence limits) of mean sleep-wake cycle variables (bedtime, waking time) during DST, compared to mean values before DST. Persons from the 'unadjusted group' advanced their waking time but did not advance their bedtime, with a reduction of an hour in the sleep period (Fig. 1). Compared to the 'adjusted group', unadjusted persons had more problems falling asleep, more diurnal somnolence and tiredness (Fig. 2). It was also found that unadjusted persons went to bed earlier before DST introduction. After DST, the sleep-wake cycle during weekends was almost identical to the phase it had before changing clock time (Valdez
et al., 1997), this effect remained for 2 weekends after DST. An actigraphic recording during the transition to DST also showed a delay in adjustment of more than 2 weeks, in some persons (Valdez, unpublished observations) (Figs. 3, 4). There were no effects on sleep-wake cycle after returning to the standard time at fall (Ramírez et al., 1994). During the process of adjustment there were two main effects in unadjusted persons (Valdez et al., 1998): A sleep deprivation effect, unadjusted persons lost 1 h of sleep; and a sleep-wake cycle effect, unadjusted persons woke earlier before DST; their sleep-wake cycle during weekends tended to adopt the same phase as before DST. Another result that suggests a sleep-wake cycle effect is the fact that returning to standard time in fall did not have any effect. It is more difficult for the circadian clock to advance than to delay the phase (Roelfsema, 1987).

Weekends
A tendency of human populations to prolong and delay sleep during weekends is well established. Workers and students with a 5–2 days work-rest cycle sleep more (30–90 min) and delay (30–120 min) their sleep-wake cycle during weekends (Webb, 1985). The delay on weekends occurs at almost all ages: in children (Anders et al., 1978; Mauldin & Meeks, 1990), adolescents (Kirmil-Gray et al., 1984), and adults (Binkley,
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1993; Renfrew et al., 1987). Andrade et al. (1993) observed that the delay on weekends increases as children reach puberty.

There are two possible explanations of delay and extension of sleep during weekends. The first takes into account that working and social activities impose limitations on the sleep period, so there is a sleep deprivation effect during weekdays. Extension and delay of sleep are part of a recovery process that takes advantage of the extra free time available during weekends. There are also changes in social activities during weekends, like going to parties and alcohol consumption that further promote these changes in the sleep-wake cycle. This homeostatic hypothesis can explain extension of sleep, but not delay of sleep, people could extend their sleep going to bed early or taking naps. The second possibility takes into account that sleep-wake cycle has circadian properties (Lavie, 2001), human circadian rhythms tend to adopt a period of more than 24 h. According to this explanation, less stringent social conditions during weekends allow delay of the sleep-wake cycle as occurs during free running studies. This circadian hypothesis would predict a lack (or only partial) synchronization to weekday’s working and social activities.
Lack (1986) studied sleep habits and difficulties in a sample of 211 university students, he found that 18% of the sample reported difficulties falling asleep, probably related to delay in sleep and wake times on weekends. Lack described 17% of the sample as a mild form of delayed sleep phase syndrome, because they have the following characteristics: a large delay of sleep times (approximately 2 h) on weekends, sleep-onset difficulties during weekdays, reduced sleep duration and increased drowsiness and irritability during weekdays, as well as deep and undisturbed sleep once they fell asleep. This paper links weekends delay of sleep with delayed sleep phase syndrome that has been classified as a sleep-wake cycle disorder due to a circadian alteration (Weitzman et al., 1981).

In order to analyze the relative contribution of sleep deprivation and circadian rhythms to the sleep-wake cycle, Valdez et al. (1996) recorded 52 female undergraduate students that attended school Monday to Friday, with two schedules: a morning schedule (07:00 to 12:00h) and an afternoon schedule (14:00 to 18:00h). The afternoon schedule group slept more, their sleep duration was identical in weekdays and weekends, but although they were not sleep-deprived during the week, they delayed their sleep-wake cycle by 24 min on weekends (Fig. 5). This delay was positively correlated with chronotype (morningness-eveningness); that is, evening type persons had
larger delays during weekends (García et al., 1999). These results suggest a circadian effect in the delay on weekends and in the adjustment to weekdays. It also suggests a dissociation of extension and delay of the sleep-wake cycle during weekends. Extension seems to be related to the homeostatic function of sleep; partial sleep deprivation during weekdays due to work and social demands, produces a pressure on sleep, so persons tend to compensate for the lost sleep during weekends. On the other hand, delay on weekends seems to be related to the circadian function of sleep, sleep-wake cycle may not become completely synchronized to the socially imposed advanced schedule during weekdays, so it returns to a delayed phase on weekends.

Machado et al. (1998) analyzed the influence of work and study schedules on sleep-wake cycle during the week. They studied three groups of undergraduate female students: no-job morning group (n = 47), no-job evening group (n = 31), and job evening group (n = 17). The two groups without job prolonged and delayed their sleep; students from the job evening group extended their sleep, but delayed only their waking times, without changing their bedtimes. This study shows that phase delay on weekends expresses differently according to study and work schedules.

Yang et al. (2001) designed a study to test the hypothesis that delay of sleep on weekends is associated to a phase delay of circadian rhythm. They recorded salivary
Figure 5. Comparison of two groups of female students. Morning group subjects reduced their sleep during weekdays; they prolonged and delayed their sleep during weekends. Afternoon group subjects were not sleep deprived during weekdays, but nevertheless there was a 24 min delay in their sleep-wake cycle.

dim-light melatonin onset (DLMO) as a measure of the circadian rhythm, on Friday and Monday nights, in 10 persons (2 female, 8 male). Recordings were programmed twice in each subject, in the following conditions: placebo (administration of mannitol) and experimental (administration of 6 mg of melatonin 5.5 h before subject’s habitual bedtime on Sunday). Melatonin administered at that time has been demon-
strated to phase advance the human circadian rhythm (Lewy & Sack, 1997). In the placebo condition there was a significant delay of 31.6 min in DLMO on Monday night compared to Friday night. In the experimental condition (melatonin administration) no delay occurred, and on Monday morning subjects rated themselves less ‘sleepy’, ‘overall feeling better’, more ‘alert’, and rated more ‘effort to do anything’, although there were no differences between the melatonin and placebo conditions in Stanford Sleepiness Scale ratings, a Multiple Vigilance Test, a nine choice reaction time, a word list memory test and the Controlled Oral Word Association test. This study provides support to the hypothesis that delay of the sleep-wake cycle is associated to a delay in melatonin circadian rhythm, and that melatonin administration can phase advance the sleep-wake cycle on weekends, with a reduction in subjective sleepiness on Monday morning.

Vacation period is another example of a small change in schedule. The free time available on vacation allows changes in the sleep-wake cycle. Foret et al. (1982) studied 49 medical students and observed differences in bedtime and rising time during working and vacation periods, they related these differences to chronotype. From the data provided by Foret et al. (1982), it is possible to calculate duration change and delay of sleep on vacation compared to the working period. On the vacation period evening time persons prolonged their sleep 77 min, bedtime delay was 89 min and rising time delay was 166 min; morning type persons prolonged their sleep 66 min, bedtime delay was 26 min and rising time delay was 92 min. So, there are no differences in sleep extension on vacation between chronotypes, but evening type persons delay more their sleep during vacation.

Conclusions

It is possible to study adjustment of sleep-wake cycle in laboratory or field settings, initial laboratory studies found a very rapid adaptation to small changes in schedule, attributing transitory effects to masking. Field studies have found that adjustment depends on variables such as individual differences in chronotype (morningness-eveningness), work schedule, sleep deprivation, and synchronization to a circadian rhythm with a period greater than 24 h. It is necessary to take these variables to the laboratory to assess their relative contribution to circadian effects or masking. The main hypothesis of this article is that small changes in schedule affect circadian rhythmicity, and some data suggest this possibility, but the few studies available on this subject preclude firm conclusions. Sometimes masking is eliminated as ‘noise’ to the circadian system, but in the analysis of human circadian rhythms it is important to identify masking mechanisms, they could be feedback signals that may contribute to modulate output of the circadian clock, specially on the interaction of human behavior with time.

These phenomena deserve further attention from chronobiologists; they offer the opportunity to study adaptation of the sleep-wake cycle in recurrent, social conditions. A large proportion of the urban population is exposed to small changes in schedule, like daylight saving time and a 5–2 days work-rest schedule. Studying these
phenomena is also relevant to some socioeconomic issues, such as the reported increase of traffic accidents (Monk, 1980; Coren, 1996; Varughese & Allen, 2001) and complaints from the population during DST; or the possible decrease in productivity and absenteeism during the ‘Blue Monday’ (Larsen & Kasimatis, 1990).

References


