Sleep times, sleep quality and subjectively perceived disturbing noise sources in a representative sample of the Swiss Population

G. Tinguely[1] and C. Cajochen[2]

Author's affiliation:

[1] Federal Office for the Environment (FOEN), CH-3003 Bern, Switzerland, gilberte.tinguely@bafu.admin.ch

[2] Centre for Chronobiology, Psychiatric Hospital of the University of Basel, CH-4012 Basel, Switzerland, Christian.Cajochen@upkbs.ch

INTRODUCTION

Sleep phase preference and social demands such as working hours can considerably differ among people. However, the physiologically driven sleep phase preference, controlled by an endogenous pacemaker in the brain, remains nocturnal in humans independent of social and other demands. Thus, it is of crucial importance for daytime functioning that sleep at night is not disturbed by environmental factors such as noise. We conducted a survey to provide data representative of the Swiss population on habitual sleep times and on different environmental noise sources that disturb sleep in order to determine at what time most people sleep so that this time can be considered as "night" which needs appropriate protection against noise disturbances. This is of urgent importance, since the population around the national airports has been complaining of being awakened by aircraft noise in the morning between 6 and 7, which according to Swiss regulation refers to as "daytime".

The current Swiss regulation has limit values for a range of environmental noise sources for day- and nighttime separately. To add to the complexity, the start time of a day and night episode depends on the various noise sources, but are currently not based on the sleeping habits of the Swiss population Furthermore, the defined times of day and night episodes are the same for workdays and weekends although, due to societal constraints, most people sleep at rather different times on free days and workdays (Borbély 1984; Roenneberg, Wirz-Justice et al. 2003; Groeger, Zijlstra et al. 2004).

Based on the above mentioned important shortcomings in the current Swiss protection ordinance, we conducted a survey in a representative sample of the Swiss population and addressed the following five main questions:

- At what time do people sleep during work and free days?
- Is there an age-related change in preferred sleep times?
- Which are the noise sources responsible for noise-related sleep disturbances?
- Does noise annoyance relate to the objectively modeled noise exposure?
- Does sensitivity to noise relate to objectively modeled noise exposure and subjective sleep quality?

The results will be discussed in the context of the regulatory question about Swiss day and nighttime limits.

METHODS

Survey procedure and sampling

In February 2011, 2009 Swiss residents aged 12 years and older living in a household with a registered fixed network who could be surveyed either in French, German or Italian were interviewed by means of CATI (computer assisted telephone interview). The survey was conducted by the LINK Institute, Lucerne, from the laboratories in Zurich, Lausanne and Lugano using a telephone interviewing program. A random quota sampling, directed by a computer assisted sample organizer program, was used. The sampling procedure within a region comprised two stages: first a household was chosen at random in the phone directory then the person was chosen according to a quota sampling. The quotas were based on the age, gender and working status of the structural data for the Swiss population in 2008-2009 according to the Federal Statistical Office (FSO).

In order to have sufficient data in all 3 regions, the number of interviews was disproportionate to the population. To account for this, the data were weighted in the analyses. The mean duration of an interview was 20.6 minutes.

Children are rarely included in surveys because it is rather difficult to interview them. Furthermore, up to the age of 10 years the bed- and rise times are usually determined by the parents. In our survey, we interviewed persons from the age of 12 years on, and we will complete the sleep time data for the younger children with the data set gathered by the Zurich Longitudinal Studies (Iglowstein, Jenni et al. 2003). These studies included 493 children followed from birth to the age of 16 years in 3 separate cohorts from the Zurich area, which formed a representative selection of the Swiss urban population (Iglowstein, Jenni et al. 2003).

Questionnaire

The questionnaire comprised questions on health and use of remedies, sleep habits, sleep disturbances and sources of disturbing noise sources; included were the questions of the 1984 survey (Borbély 1984), the Munich Chronotype Questionnaire (Roenneberg, Wirz-Justice et al. 2003) and the short form of a noise sensitivity questionnaire (Zimmer and Ellermeier 1998). The questions were adapted for telephone interviews in Swiss German and translated into French and Italian.

Sleep and wake-up time were assessed with the following specific question: ‘when are you ready to sleep’ and not ‘when are you going to bed’ and ‘when do you wake up’ and not ‘when do you get up’. Thus, here we aimed at gathering people’s actual sleep times instead of bedtime, which was asked additionally considered in a separate question.

Objective traffic noise data

We used the objective noise data of the Swiss noise database sonBase (FOEN 2009; FOEN 2009b), which maps the traffic noise of the entire country on a scale of 10 x 10 meters with the number of people exposed to noise. SonBase provides data based on the vectorised 1 : 25 000 national map issued by the Federal Office of Topography swisstopo (vector 25). The objective noise level is the rating level (Lr) in dB(A). As expected not all interviewee accepted to provide their exact address. Nevertheless, we were able to receive objective noise measures in 1458 people, for whose address location a reliable validation of noise emission was possible.

Data analyses and statistics

For each question, we first tested whether the answer distribution between subsets was different from the distribution of the whole dataset by means of a Chi-square test. The means of subsets were tested by T-tests. For the relation between subjective and objective traffic noise measures, Spearman's Rank correlations were calculated.

RESULTS

At what time do people sleep during work and free days?

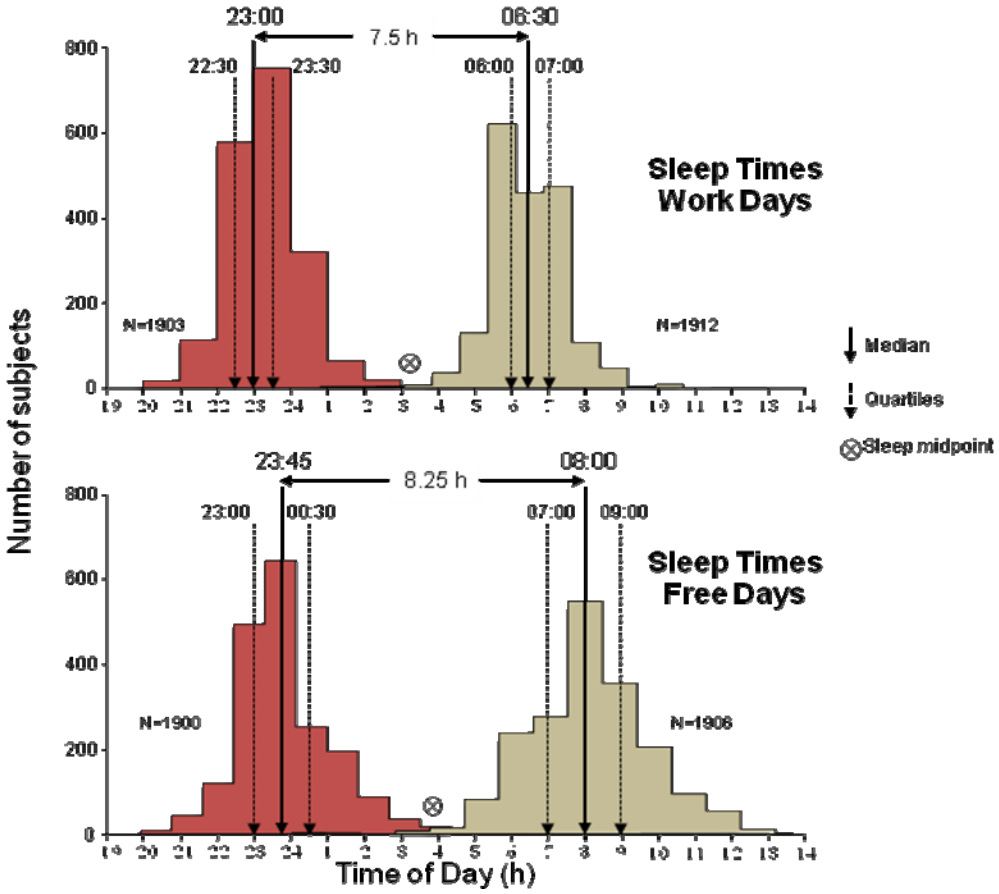

Figure 1: Sleep times in a representative sample of the Swiss population

Figure 1 shows the distribution of sleep times on work days and free days for persons aged 12 and more. On work days, the first quartile of sleeping time was at 22:30, the median at 23:00 and the upper quartile at 23:00. On free days, there was a general shift to later times 23:00, 23:45 and 00:30 respectively. On work days, the first quartile of wake up times was at 06:00, the median at 06:30 and the upper quartile at 07:00. On free days, these times delayed to 07:00, 08:00 and 09:00, respectively. This delay shift on free days was much more pronounced for the wakeup- than the sleep times.

Is there an age-related change in preferred sleep times?

Figure 2 shows the age-related changes in the sleep times on work days and free days separately for persons aged 12 and more. The median and lower quartile of sleep times on work days were remarkably stable from the age of 16 on with a slight trend towards later times with age in contrast to the ones on week-ends that were

latest for the age of 16 to 19 and then became earlier with increasing age, finally approaching the times for work days at the age of 70. The median wake-up time on work days was rather stable across ages with earliest wake-up times for the 40 to 59 years old people whereas the upper quartile tended to become later across ages. The most striking effect of age represented the wake-up times on weekends with median wakeup times being latest for the 12 to 19 years old people and advancing by one hour per decade between 20 and 39 followed by a slower rate until the earliest time is reached in oldest persons. The upper quartile became later from 12 to 19 where it was at its latest at twelve o'clock and then advanced to an earlier time more or less like the median.

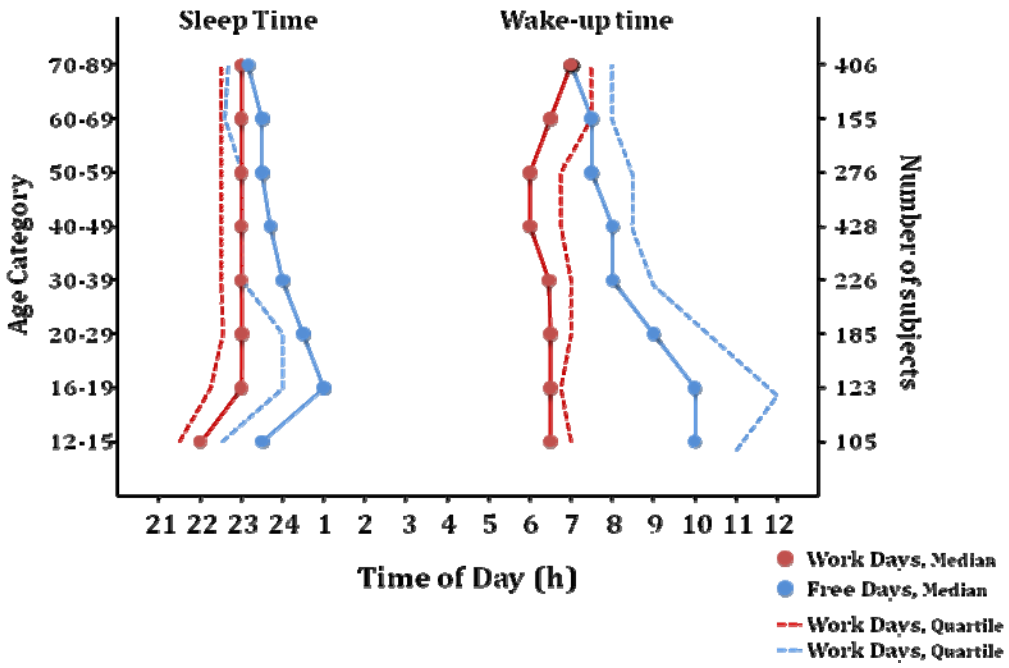

Figure 2: Age-related changes in sleep times in a representative sample of the Swiss Population

Which are the noise sources responsible for noise-related sleep disturbances?

The noise sources, which awakened people, hindered them to fall asleep or get back to sleep, are listed in descending order in Table 1. For the ranking, the answers 'very often' were weighed by a factor of 4, 'often' of 3, 'occasionally' of 2 and 'seldom' was taken unchanged and then added to a score for each noise source.

Table 1: Answers (in %) to the question 'when sleeping badly are you awakened or hindered to fall asleep by one of the following sounds?'

	Very often	Often	Occasionally	Seldom	Never	Score
Children or pets	2.2	5.8	12.9	13.8	65	65.8
Road traffic	1.3	3.9	12.9	13.4	68.3	56.1
Neighbors	0.6	2.8	8.6	16.7	71.1	44.7
Restaurants, music, events	0.5	1.4	5.9	13.6	78.4	31.6
Church bells	1.2	1.9	6	7.8	83	30.3
Aircraft	0.9	1.6	5.7	9.6	82	29.4
Rail	0.5	0.9	5.5	6.1	86.7	21.8
Cow bells	0.3	0.4	2.3	4.3	92.5	11.3
Industry	0.2	0.6	1.2	2.5	95.1	7.5

Frog croaking	0.2	0.2	1.2	2.2	96	6
Sounds by other animals (dogs, cats, foxes, birds)	0.4	1.6	7.6	11	79.1	32.6
Other sounds (people in the house, on the street, bed partner)	1.2	1.8	7	8	81.5	32.2

Does noise annoyance relate to the objectively measured noise exposure?

The ranking of the daytime noise sources is listed in Table 2 for daytime on workdays at home, in Table 3 for daytime on weekends at home and in Table 4 for the workplace. The score was calculated similarly as for the nighttime noise sources.

Table 2: Answers (in %) to the question 'how much are you annoyed or incommoded by the following sound sources during the day on work days at home?'

	Very much	Much	Middle	A little	Not at all	Score
Road traffic	3.2	3.2	10.6	23	59.7	66.6
Machines and equipment	2.8	3.3	9.8	21	62.7	61.7
Neighbors	2.3	2	7.6	18.9	68.9	49.3
Aircraft	2.4	1.9	6.4	15.6	73.4	43.7
Animals	2	1.4	4.5	13.9	78	35.1
Church bells	2.8	1.3	4.1	10.7	80.8	34
Rail	2.5	1	4.9	8.3	82.9	31.1
Restaurants, music, events	2.5	1.3	3.4	8.6	83.9	29.3
Other sounds	0.6	1.4	3.8	6.1	87.5	20.3
Industry	2.5	0.7	1.8	4.2	90.5	19.9

Table 3: Answers (in %) to the question 'how much are you annoyed or incommoded by the following sound sources during the day on weekends at home?'

	Very much	Much	Middle	A little	Not at all	Score
Road traffic	2.1	2.4	8.4	19.8	67	52.2
Neighbors	1.5	1.8	6.2	16.2	73.9	40
Aircraft	1.7	1.5	4.8	13.2	78.4	34.1
Machines and equipment	1.5	1.3	4.9	12.3	79.7	32
Church bells	1.7	1	3.7	9.3	83.9	26.5
Animals	1.3	0.9	3.3	11.5	82.6	26
Rail	1.4	0.8	3.4	8.1	86	22.9
Restaurants, music, events	1.3	0.9	3.1	7.5	86.8	21.6
Industry	1.3	0.5	1	2.2	94.8	10.9
Other sounds	0.8	0.9	1.6	4.7	91.5	13.8

Table 4a: Answers (in %) to the question 'how much are you annoyed or incommoded by… ?' (only employed people asked, 58.4 % of interviewees)

	Very much	Much	Middle	A little	Not at all	Score
Sounds produced at the working place	2.7	6.6	17.5	21.2	51.4	86.8
Non company related sounds	1.7	2.3	7.9	11.2	76.2	40.7

Table 4b: Answers (in %) to the question 'by which non company related sounds?'

Road traffic	42.8

Construction noise	22.4
Humans	10.5
Aircraft	9.0
Railway	8.3

Table 5: Spearman's Rank correlation between subjectively rated noise annoyance and objectively modeled noise in the environment a person lives; all values were statistically significant with p<0.001

Noise source and time	Road day	Road night	Plane day	Plane night	Train day	Train night
Correlation Coefficient	0.12	0.12	0.12	0.10	0.22	0.23

Does sensitivity to noise relate to objectively modeled noise exposure and subjective quality?

There were no significant correlations between subjective sensitivity to noise and objectively modeled noise exposure (all r values <0.05, all p values > 0.2). However, people with high scores on the noise sensitivity questionnaire also rated their sleep quality worse. Thus, correlation analyses, yielded significant negative correlation between sensitivity to noise and sleep quality (r=-0.23, p<0.0001).

DISCUSSION

Sleep times in Swiss residents?

Our survey yielded clear work- versus free days as well as age-dependent effects on sleep times in Swiss residents. These effects were most pronounced in the wake up times, which encompassed a broad time range from 04:00 to 13:00. Wake up times differed considerably between work - and free days, particularly for young residents (< 30 years). In contrast, sleep times differed to a lesser extent than wake-up times between work - and free days. The difference in sleep phase preference between workdays and weekends corroborates earlier findings in the literature (Borbély 1984; Roenneberg, Wirz-Justice et al. 2003; Groeger, Zijlstra et al. 2004; Frey, Balu et al. 2009; NSF 2010) and gives evidence to a sleep debt, which accumulates during the working week (Taillard, Philip et al. 1999). This phenomenon has also been referred to as a "social jet lag", since societal working demands during the week hinders biological demands for sleep (Roenneberg et al. 2003). The observed averaged sleep duration of 7.5 hours on work days in our Swiss resident sample was about 30 minutes longer when compared to a similar survey in a representative sample of some 2000 British residents (Groeger et al. 2004).

Since, in our survey Swiss residents < 12 years were not interviewed, we included information on bed- and wake time from the Zurich longitudinal studies. However, in this survey sleep times were not given separately for workdays and weekends. Thus, table 6 just shows bed- and wake times from infancy to teen age (up to <14 years).

Table 6: Bedtime and wake time (3rd cohort, in hours:minutes with SD) of infants to adolescents (from Table 2 in (Iglowstein, Jenni et al. 2003)

	6 Months	1 Year	3 Years	5 Years	10 Years	14 years
Bedtime	20:16 (1:08)	19:46 (0:50)	20:07 (0:42)	20:11 (0:38)	20:59 (0:40)	22:02 (0:37)
Wake time	7:13 (0:13)	7:19 (0:52)	7:35 (0:50)	7:20 (0:39)	6:56 (0:29)	6:30 (0:20)

The proportion of children in the Swiss Population (2008-2009 FSO) is of around 6 % for the 0 to 5 years old, of 5 % for the 6 to 10 years old and of 4 % for the 11 to 14 years old. The 12 to 19 years old account for approximately 9 % of the population.

Taking the data of our and of the Zurich survey, we calculated that around 9 % of the population is asleep at 21:00 on work days and weekends, whereas at 22:00, 20 % of the population is asleep on workdays and 16 % on free days. At 06:00 in the morning, 78 % of the population is still asleep on workdays and even more (95 %) on free days, while at 07:00 this proportion falls to 35 % on workdays and 81 % on free days. On free days, 25 % of the population aged 12 and more were still asleep at 09:00. The median wake up time for 12 to 19 years old residents was 10:00 and the upper quartile 11:00 for the 12 to 15 years old and 12:00 for the 16 to 19 years old respectively.

Based on our survey, we have evidence that a nightly protection from noise between 22:00 and 06:00 may not be sufficient. This is particularly true for the morning value (i.e. 6:00) with 78% of the population still asleep on workdays and 95% on free days. Thus, noise protection only until six o' clock in the morning may not be appropriate for a large part of the population. Since the timing of sleep is driven by an intrinsic biological clock, it is difficult to force people to sleep during the most quiet time of the night (i.e. midnight to 6 am), which would only comprise 6 hours of sleep. According to our survey, 90% of the Swiss residents sleep more than 6 hours on work days and almost all (95%) on weekends. Thus, according to our results, a time window of 9 hours for sleep ideally placed between 22:00 and 7:30 accommodates 90% of the Swiss population on work days, while these time points considerably shift on free days for 90% of the population as follows: 10 hours of sleep ideally placed between 22:30 and 10:00. Although these times are optimal for 90% of the population, the late chronotypes (about 5 to 10% of the population) who suffer most of the misalignment of biological and social time leading to shortened sleep (Wittmann, Dinich et al. 2006) would still not fit in the proposed time window for sleep in order to get enough sleep. Thus, it was no coincidence that adolescents and young adults in our survey showed the latest wake-up times on weekends. Indeed, there is a shift of the sleep phase preference during the adolescence (Carskadon, Acebo et al. 1997; Carskadon, Acebo et al. 2004; Frey, Balu et al. 2009).

The consequences of poor or too little sleep are daytime fatigue, drowsiness and sleepiness, which lead to impaired attention and learning. This can lead to accidents, injuries and deaths due to lapses in attention and delays in reactions for instance while driving. In the US, young drivers under the age of 25 are involved in more than half of the fall-asleep crashes (National Sleep Foundation. Adolescent Sleep Needs and Patterns). On the longer term, poor sleep and sleep curtailment has effects on performance and health such as cardiovascular and metabolic diseases (Carskadon and Dement 1981; Van Dongen, Maislin et al. 2003; Curcio, Ferrara et al. 2006; Van Cauter, Holmback et al. 2007; Meerlo, Sgoifo et al. 2008; Van Cauter, Spiegel et al. 2008; Spiegel, Tasali et al. 2009).

It has been repeatedly shown that noise has a negative impact on sleep (Muzet 2007). Even young healthy good sleepers can be awakened by noise of only 40 dB(A) (Dang-Vu, McKinney et al.). The current noise impact thresholds in Switzerland for sensitivity zone II are of 60 dB(A) for daytime and 50 dB(A) for night time, calculated based on yearly mean levels. Thus, for short periods much higher levels are possible.

Which are the noise sources responsible for noise-related sleep disturbances?

The results of the noise sources disturbing sleep suggest that noise from the family, pets and neighbors are as disturbing as road traffic noise, which all comprise the top

three hits according to table 1. Besides these top three noise sources, other important sources, in terms of number of people disturbed by noise at night, was noise from restaurants, music and events as well as church bells, which were more disturbing than noise from aircrafts and trains in Switzerland.

Does noise annoyance relate to the objective noise exposure?

In Tables 2 to 4, the sources of daytime noise disturbances are listed in ranked order. As for the night, road traffic was on the first place on workdays and on weekends. This is in accordance with the rank order in number of people exposed above threshold levels as calculated in sonBase. Although, there are much more people exposed to railway noise above threshold levels than to aircraft noise, there were more people being annoyed or disturbed by aircraft noise both on workdays and on weekends. However, most people were disturbed by neighborhood noise and on workdays also by machines and equipment. The correlation between subjective noise assessment and objective noise exposure was statistically significant for all available variables but with relatively low r-values. However, this indicates that objectively modeled noise exposure can be used as a proxy for subjective noise annoyance in a specific region.

Does sensitivity to noise relate to subjective sleep quality and objectively modeled noise exposure?

Noise sensitivity as assessed with a short questionnaire did not correlate with modeled noise exposure. This either indicates that noise sensitive people avoid “noisy” places for living, or that noise sensitivity is not influenced by the noise levels of the environment. However, as intuitively assumed, noise sensitive people also reported impaired sleep quality, as indexed by a negative correlation between noise sensitivity and sleep quality.

In summary, our survey data give evidence that the critical nighttime period for noise protection should ideally comprise 9.5 hours from 22:00 to 07:30 on workdays and 11.5 hours from 22:30 to 10:00 on free days. With appropriate noise protection this time window could ideally allow undisturbed sleep for 90% of the Swiss population. Besides noise of the closest vicinity by family members, pets and neighbors, road traffic noise is the most common complaint of Swiss people affecting their sleep and did significantly correlate with modeled noise data.

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