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Yawning and subjective sleepiness in the elderly

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SUMMARY Yawning is related to sleep/wake transitions and time of day, probably reflecting the time course of sleepiness. As aging modifies sleep–wake and sleepiness rhythms, we suppose that yawning frequency and its time course vary as a function of age. Thirteen aged healthy subjects (77.15 ± 4.09 years) and 12 young adults (24.41 ± 3.31 years) were instructed to keep their habitual sleep schedules for three consecutive work-days, during which they were required to signal every yawning occurrence and to evaluate hourly their sleepiness level. Results showed that aged subjects yawn less frequently than young adults, particularly during morning and mid-afternoon hours. The time course of yawning was different between the two age groups: aged subjects showed earlier morning peak and evening rise compared with young adults; in addition, aged subjects showed two minor peaks in-between. Differences as a function of age in the time course of yawning were associated with differences in the time course of sleepiness. The only exception pertained to the early morning yawning peak, which was close to the awakening but it was not associated with high sleepiness in aged subjects. Our study discloses that aging modifies yawning frequency and its time course. Furthermore, as in the elderly yawning after the awakening is not associated with high sleepiness level as in young adult, we put forward that sleepiness level and the proximity of sleep/wake transitions could separately affect yawning.

KEYWORDS aging, sleep, sleepiness, yawning

INTRODUCTION

Yawning is an involuntary and stereotyped behavior common to several vertebrate species (for reviews see Baenninger, 1997; Provine, 2005). It is a complex act consisting of a long inspiration phase (that comprises mouth opening, dilatation of pharynx, larynx and thorax, and diaphragm lowering), a subsequent extensive contraction of the facial muscles together with a brief interruption of ventilation, and a final expiration phase which involves the relaxation of all participating muscles (Barbizet, 1958). In addition, stretching of the limbs frequently accompanies yawning (Baenninger, 1997; Provine, 2005).

The study of yawning correlates and function has recently raised a growing interest in the scientific literature. Yawning frequency is enhanced in those conditions involving boredom (Provine and Hamernik, 1986) and prominent sleepiness (Provine *et al*., 1987), and it has been suggested that yawning arises in order to counteract low levels of arousal (Baenninger, 1997; Baenninger *et al*., 1996). This hypothesis is supported by the motility increase (Baenninger *et al*., 1996) and brain activation associated with yawning occurrence (Karasawa *et al*., 1982; Kasuya *et al*., 2005). Nevertheless, another study failed to find brain activation after yawning in patients with excessive daytime sleepiness (Guggisberg *et al*., 2007).

Among the effects of yawning, its contagious response must be included: witnessing a yawn, or even thinking about it, is effective to trigger yawns in the observer (Provine, 1986). Taking into account this phenomenon, the author suggested that the act of yawning could represent a para-linguistic signal of one individual's drowsiness which synchronizes the behavioral and psychological state of the remaining members of a group (for review see Provine, 2005).

Studies focused on adult human individuals provided evidence that yawning occurs about seven to eight times per day (Baenninger *et al*., 1996) and that it is more likely to take place close to both wake–sleep and sleep–wake transitions

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(Provine *et al.*, 1987). Furthermore, yawning is often associated with stretching immediately after the awakening, which has been supposed to be a signal for the preparation for action (Provine *et al.*, 1987).

Yawning also varies across time of day (Baenninger *et al.*, 1996). It peaks in the morning, after the awakening, and decreases in the following hours reaching a minimum around noon. A second peak is observed in the late afternoon, which is immediately followed by a dip. Yawning frequency increases over subsequent hours towards its maximum level that occurs late in the evening, i.e. close to bedtime when sleepiness reaches high levels.

The time course of yawning is linked to the development of the circadian sleep–wake rhythm: the time course of yawning found in young adult is indeed absent in subjects who have not yet developed circadian rhythms and exhibit a polyphasic sleep–wake pattern such as babies in very early infancy (Giganti *et al.*, 2007). The close relationship between the circadian rhythms and yawning has been further highlighted by the finding that the differences in sleep–wake and sleepiness rhythms between extreme chronotypes (i.e. evening and morning types) affect yawning frequency and its time course (Zilli *et al.*, 2007).

Circadian rhythms change considerably with aging (for a review see Myers and Badia, 1995). The most evident differences are referred to frequency and timing of sleep episodes with an increase of diurnal naps occurrence (Bliwise *et al.*, 2005; Foley *et al.*, 2007) and a phase advance of nocturnal sleep episode, which is also interrupted by frequent and long-lasting awakenings (Bliwise, 1993; Salzarulo *et al.*, 1999). These changes are associated with modifications in the time course of sleepiness during the 24 hours. Aged subjects usually claim annoying sleepiness during the afternoon (for reviews see Miles and Dement, 1980; Bliwise, 1993), while they are more alert than younger subjects during night-time (Richardson *et al.*, 1982) and in the morning after the awakening (Carrier *et al.*, 1997). The analysis of subjective alertness rhythm across aging consistently confirms a phase-advance and higher levels in the nocturnal hours (nadir), which determine an amplitude reduction and an increase of the mean level (mesor) of alertness (Monk *et al.*, 1996).

Up to now there are no systematic studies on yawning in the elderly. Only Walusinski (2006) shortly mentioned a reduction of yawning behavior in aged subjects. This finding could be explained by a reduced capacity to produce yawning. Alternatively, taking into account the relationship among yawning, sleep and sleepiness, yawning frequency reduction could be due to the age-related changes in the phase relationship between sleep–wake and sleepiness rhythms.

We hypothesize that aging could affect the yawning frequency and its time course across wakefulness, as well as its relationship with sleep onset and awakening. In fact, we assume that the age-related reduction in sleepiness level at awakening and during morning hours should be paralleled by a lower yawning frequency, whereas the increased sleepiness in the afternoon reported by aged subjects should be associated with enhanced yawning during this period.

METHODS

Subjects

Two groups of subjects were selected for the study: aged group (13 subjects, 6 females and 7 males; age, mean ± standard error: 77.15 ± 1.134) and young adults group (12 subjects, 6 females and 6 males; age: 24.41 ± 0.313). Inclusion criteria were: (i) absence of any pathologies or medications which could alter sleep and sleepiness, (ii) absence of cognitive and mnestic impairment (assessed by means of the Mini-Mental State Examination and the Wechsler Memory Scale), (iii) absence of sleep complaints (assessed through an interview and by means of the Pittsburgh Sleep Quality Index, Buysse *et al.*, 1989), and (iv) absence of night-time shift work.

Procedure

Each subject was required to fill out an Italian version (Mecacci and Zani, 1983) of the Morningness Eveningness Questionnaire (MEQ, Horne and Ostberg, 1976) and instructed to wear (on the non-preferred arm) a wrist activity monitor (Actiwatch-Plus; Cambridge Neurotechnology Ltd, Pampisford, Cambridge, UK) for three consecutive days (from Tuesday, 10.00 hours to Friday, 10.00 hours). Throughout this period subjects were also required: (i) to keep their habitual sleep times, (ii) to signal each yawn pushing an event marker button placed on the top of the actiwatch; (iii) to fill out a sleep log before retiring to bed, and (iv) to evaluate their sleepiness once a hour throughout wakefulness, using a bipolar 100-mm visual analog scale.

Data analysis

Bed times (bedtime and get-up time) and morningness score were obtained, respectively, from sleep log and MEQ filled out by the subjects themselves. Sleep times (sleep onset and awakening), time in bed, sleep latency, sleep duration and sleep efficiency were evaluated through the analysis of activity level (Sleep Analysis Software, Copyright Cambridge Neurotechnology Ltd, Version 3.24). Yawning frequency per hour was computed for each subject calculating the ratio between total number of yawns per day and wakefulness duration. Data were compared between the two groups through Student's *t*-test for unpaired samples.

The time course of yawning across the wakefulness period common to all subjects (i.e. time intervals from 9.00 to 22.00 hours) was assessed through ANOVA for repeated measures, with 'age group' as between factor, 'hour' as within factor and number of yawns as dependent variable. The relationship between yawning and sleep episode was assessed through ANOVA for repeated measures over the 5 h preceding sleep onset and following final awakening, with 'age group' and 'transition' (i.e. the shift from wake to sleep and, vice versa, from sleep to wake) as between factors, 'hour' as within factor and number of yawns as dependent variable.

Sleepiness ratings of each subject were transformed into *z*-scores in order to avoid biases due to the subjective nature of the scale. Then, the time course of sleepiness across wakefulness and the relationship between sleepiness and sleep episode have been assessed by the same analyses applied for yawning.

The significance level was set at $P \leq 0.05$. For overall ANOVA significant effects, differences between subjects were evaluated using Student's *t*-test for unpaired samples, whereas differences within subjects were tested applying separately for each age group an ANOVA for repeated measures.

The relationship between the time course of yawning across wakefulness and the time course of sleepiness was assessed through correlation analysis. Pearson's *r* coefficient between *z*-transformed scores of yawning and sleepiness was calculated for each subject. Then, each group's values have been tested for significance against the null-hypothesis ($r = 0$) through *t*-test for one sample.

To determine whether changes as a function of age in the time course of yawning are associated with changes in the time course of sleepiness, differences between young and aged subjects were computed for both yawning and sleepiness scores. Then, Pearson's *r* coefficient between the obtained differences has been calculated.

RESULTS

Sleep

Aged group showed advanced bedtime, sleep onset and awakening compared with the younger group, together with higher morningness score (Table 1). Moreover, aged subjects spent more time in bed than young adults, whereas sleep latency and sleep duration did not differ between the two age groups; as a result, sleep efficiency was reduced in the aged subjects (Table 1).

Yawning

The analysis of the overall yawning frequency showed that aged subjects yawn less than young adults: yawning frequency per hour was, respectively, 0.323 ± 0.079 and 0.638 ± 0.108 (mean ± standard error, $t = 2.324$, d.f. = 23, $P = 0.029$).

Yawning frequency across wakefulness (Fig. 1a) was affected by 'age group' ($F_{1,23} = 5.761$, $P = 0.025$), with significant interaction between 'age group' and 'hour' ($F_{13,299} = 1.824$; $P = 0.039$). The number of yawns was lower in the aged group than in the younger one during morning hours and in the mid-afternoon (Fig. 1a). As to the time course of yawning within the

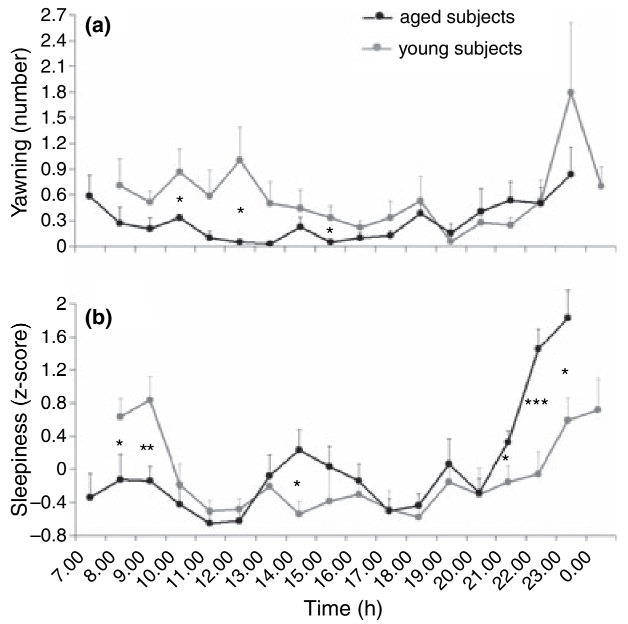

Figure 1. Time course of yawning frequency (a) and sleepiness level (b) across wakefulness. Hourly mean value ± standard error is reported separately for each age group. Asterisks indicate statistically significant differences between groups (*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$).

Table 1 Sleep characteristics in aged and young subjects

	Aged group, n = *6 F, 7 M (age = 77.15 ± 1.13)*	*Young group,* n = *6 F, 6 M (age = 24.41 ± 0.313)*	t-*test* (P)
Bed times			
Bedtime (h)	23.04 ± 0.19	0.47 ± 0.22	3.475 (0.002)
Get-up time (h)	7.47 ± 0.14	8.34 ± 0.20	1.941 (NS)
Morningness–eveningness			
Score	57.077 ± 2.299	50 ± 1.603	2.205 (0.04)
Sleep times			
Sleep onset (h)	23.29 ± 0.20	1.06 ± 0.23	3.112 (0.005)
Awakening (h)	7.36 ± 0.15	8.31 ± 0.20	2.215 (0.037)
Sleep measures			
Time in bed (h)	8.42 ± 0.18	7.51 ± 0.08	2.534 (0.021)
Sleep latency (h)	0.24 ± 0.02	0.20 ± 0.04	0.753 (NS)
Sleep duration (h)	6.55 ± 0.20	6.40 ± 0.08	2.025 (NS)
Sleep efficiency (%)	79.35 ± 2.324	85.03 ± 1.356	2.065 (0.05)

Mean ± SE of each parameter is indicated. NS, not significant.

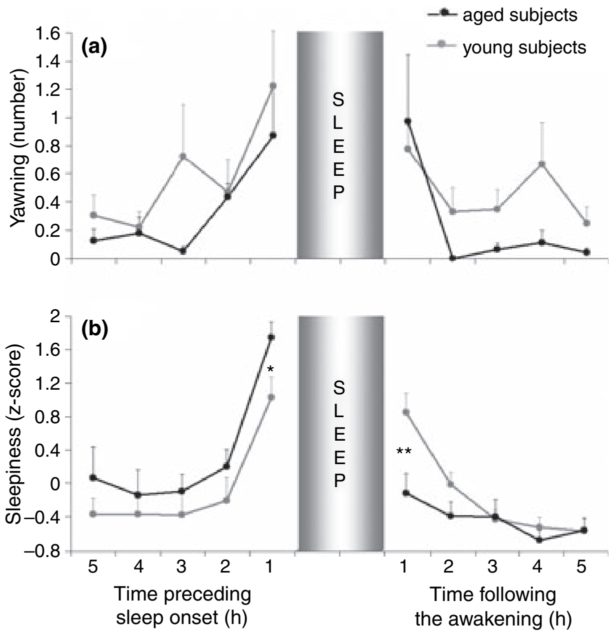

Figure 2. Time course of yawning frequency (a) and sleepiness level (b) in the 5 h preceding sleep onset and following the awakening. Hourly mean value ± standard error is reported separately for each age group. Asterisks indicate statistically significant differences between groups (*$P \leq 0.05$; **$P \leq 0.01$).

aged group, yawning frequency decreased during morning hours and it increased during the evening, showing two minor peaks in-between ($F_{13,156} = 2.067$; $P = 0.019$; Fig. 1a). The time course of yawning within the young group showed that yawning frequency decreases across daytime, reaching its lowest level in the evening, and it increases thereafter ($F_{14,154} = 2.231$; $P = 0.009$; Fig. 1a).

As to the relationship between yawning and sleep episode (Fig. 2a), yawning frequency in the 5 h preceding sleep onset and following final awakening was affected by 'age group' ($F_{1,46} = 5.5$, $P = 0.023$), 'hour' ($F_{4,184} = 2.58$; $P = 0.038$) and by the interaction between 'hour' and kind of 'transition' ($F_{4,184} = 6.73$, $P = 0.001$). In particular, yawning frequency progressively increased approaching sleep onset in both age groups (Fig. 2a). Conversely, the time course of yawning after the awakening was different between the two age groups. Although yawning frequency decreased starting from the first hour after the awakening in both age-groups (Fig. 2a), aged subjects yawned less frequently than young adults in the second hour after the awakening and they displayed the same tendency at the third, fourth and fifth hour.

Sleepiness

The time course of sleepiness across the wakefulness (Fig. 1b) was affected by 'age group' ($F_{1,23} = 4.338$, $P = 0.049$), 'hour' ($F_{13,299} = 5.441$, $P = 0.001$), with a significant interaction between 'age group' and 'hour' ($F_{13,299} = 3.294$; $P = .001$). Namely, aged subjects rated themselves less sleepy than young subjects at 8.00 and 9.00, whereas the contrary was observed at 14.00 and from 21.00 to 23.00 hours (Fig. 1b). The time course of sleepiness within aged subjects showed a slight peak early in the morning, followed by two other peaks, respectively, early in the afternoon and early in the evening; afterwards, sleepiness levels linearly rose approaching bedtime ($F_{13,156} = 6.931$; $P = 0.001$; Fig. 1b). The time course of sleepiness in young subjects showed the highest levels in the first two and in the last two waking hours ($F_{14,154} = 2.9$; $P = 0.001$; Fig. 1b).

The analysis of the relationship between sleepiness and sleep episode (Fig. 2b) evidenced that sleepiness level in the 5 h preceding sleep onset and following awakening is affected by 'transition' ($F_{1,46} = 7.988$, $P = 0.007$), with significant interaction between 'age group' and 'transition' ($F_{1,46} = 5.373$, $P = 0.025$). In fact, aged subjects rated themselves sleepier before falling asleep than after the awakening, whereas young subjects did not show the same difference (Fig. 2b).

Sleepiness level was also affected by 'hour' ($F_{4,184} = 14.126$; $P = 0.001$), with a significant interaction between 'hour' and 'transition' ($F_{4,184} = 30.495$, $P = 0.001$). Actually, both age groups showed that sleepiness increases in the hour preceding sleep onset and decreases in the hour following the awakening (Fig. 2b). Nevertheless, aged subjects reached higher values than their younger counterparts just before sleep, whereas the reverse was observed immediately after the awakening (Fig. 2b).

Relationship between yawning and sleepiness

Yawning frequency across wakefulness positively correlated with time course of sleepiness in both age groups (aged subjects: $r = 0.288 \pm 0.076$, $t = 3.769$, d.f. = 12, $P = 0.003$; young subjects: $r = 0.215 \pm 0.077$, $t = 2.802$, d.f. = 11, $P = 0.017$). Moreover, differences between the two age groups in the time course of yawning significantly correlated with differences in the time course of sleepiness ($r = 0.582$, d.f. = 15, $P = 0.018$).

DISCUSSION

Overall yawning frequency is reduced in aged subjects compared with their younger counterparts, supporting the previous report by Walusinski (2006). A remark is needed to correctly interpret our results. As the present study has been entirely based on subjective reports, we are clearly referring to yawning which subjects are aware of. Despite this potential bias, we applied this procedure because direct observation by the experimenter could inhibit yawning (Provine, 1986). Furthermore, we carefully excluded aged subjects with impaired memory in order to minimize differences between the two age groups concerning procedure fulfilment.

It is noteworthy that the reduction of yawning frequency in aged subjects is not spread throughout wakefulness: aged subjects yawn less frequently than young adults during the morning and in the mid-afternoon. This result could be explained by the age-related shift towards morningness, previously highlighted (for review, Monk and Kupfer, 2007) and replicated in the present study. In fact, a recent research (Zilli *et al.*, 2007) emphasized that morning-types yawn less frequently than evening-types particularly during daytime.

Our study also underscores that the time course of yawning across wakefulness differs between the two age groups. Although both elderly and young subjects yawn more frequently early in the morning and late in the evening, aged subjects show earlier morning peak and evening rise compared with the young adults, according to the earlier sleep times. In addition, aged subjects exhibit two minor yawning peaks, which occur early in the afternoon and early in the evening.

Several factors such as boredom (Provine and Hamernik, 1986) and the view of yawning individuals (Provine, 1986, 1989) also modify yawning frequency. Thus, it could be argued that differences with age in daily-life could interfere with yawning production. However, we recruited old subjects amongst healthy and independent persons who live on their own and participate to social activities in order to make as slight as possible the disparity between young and elderly individuals. Hence, it is tenable that age *per se* could reliably account for differences in yawning frequency and its time course.

Our results show that the time course of sleepiness varies as a function of age in agreement with previous findings (Carrier *et al.*, 1997; Monk *et al.*, 1996; Munch *et al.*, 2005). Moreover, the time course of sleepiness across wakefulness is related to the time course of yawning in both age groups. This finding is consistent with the association between yawning and sleepiness emphasized by previous researches (Guggisberg *et al.*, 2007; Provine *et al.*, 1987; Zilli *et al.*, 2007) and it underscores that this link is evident even in the elderly.

As we hypothesized, changes as a function of age in the time course of yawning are associated with changes in the time course of sleepiness. The lower sleepiness levels reported by the aged subjects during morning hours could account for the reduction of yawning frequency observed in this part of the day. It is also noticeable that the two additional yawning peaks, detected in the midst of wakefulness period in the elderly, approximately correspond to sleepiness rises. Furthermore, the advanced evening rise in yawning frequency showed by aged subjects matched up with the advanced sleepiness increase.

Concerning the relationship between yawning and sleep episode, both aged and young subjects show an increase of yawning frequency before sleep and a decrease after the awakening, with yawns peaking in the hour preceding sleep onset and in the hour following sleep termination. However, aged subjects yawn less frequently than young adults from the second hour following the awakening. In other words, young adults progressively reduce yawning frequency after the end of sleep, whereas aged subjects show a steeper reduction and yawns become virtually absent shortly after the awakening. Given the link between yawning and stretching after the awakening previously evidenced in the young adult (Provine *et al.*, 1987), it would have been interesting to verify this association in the elderly; unfortunately, our procedure missed to collect information about stretching.

It is remarkable that the rise of yawning before sleep parallels the increase of sleepiness in both age groups, whereas yawning peak after the awakening is not associated with high sleepiness level in the aged subjects. This discrepancy suggests that the time course of subjective sleepiness by itself could not give an explanation for all of the yawning frequency oscillations: the relationship between yawning frequency and the proximity of wake–sleep and sleep–wake transitions should also be taken into account. It seems reasonable to suppose that sleepiness level and sleep episode proximity could separately affect yawning, even though further researches including sleep–wake rhythm manipulation and sleepiness objective measurement are necessary to clarify their respective role.

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