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RESEARCH ARTICLE

Is snoozing losing? Why intermittent morning alarms are used and how they affect sleep, cognition, cortisol, and mood

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Summary

Pressing the snooze button is a common way to start the day, but little is known about this behaviour. Through two studies we determined predictors and effects of snoozing. In Study 1 ($n = 1732$) respondents described their waking habits, confirming that snoozing is widespread, especially in younger individuals and later chronotypes. Morning drowsiness and shorter sleep were also more common for those who snooze. Study 2 was a within-subjects laboratory study (with polysomnography) on habitual snoozers ($n = 31$), showing that 30 min of snoozing improved or did not affect performance on cognitive tests directly upon rising compared to an abrupt awakening. Bayes factors indicate varying strengths of this evidence. Snoozing resulted in about 6 min of lost sleep, while preventing awakenings from slow-wave sleep (N3). There were no clear effects of snoozing on the cortisol awakening response, morning sleepiness, mood, or overnight sleep architecture. A brief snooze period may thus help alleviate sleep inertia, without substantially disturbing sleep, for late chronotypes and those with morning drowsiness.

KEYWORDS
cognitive function, drowsiness, intermittent alarms, mood, sleep inertia, snooze

1 | INTRODUCTION

Since the earliest user-friendly versions of a 'delayed-alarm mechanism button' were patented in the early 1950s (e.g., E. L. Gordon, 1951), snoozing, or using intermittent alarms to postpone final waking, has become a common feature of waking up. A survey of almost 20,000 activity-tracking wristwatch users indicated that 50% of respondents hit the snooze button at least once every morning (Roitmann, 2017). A more recent study of 450 full-time working professionals had similar results and found that those who snooze have a generally positive attitude towards this behaviour (Mattingly et al., 2022). Furthermore, women, later chronotypes, and those lower in conscientiousness were more likely to report snoozing. Although reasons such as 'not being able to get out of bed on the first alarm' have been given for snoozing (Mattingly et al., 2022), information is still scarce regarding why people choose to do this, and whether, or how, this behaviour affects them cognitively, physiologically, and emotionally.

Although there is no previous research on the effects of snoozing per se, drawing from the fields of sleep inertia and sleep deprivation, there are several possible consequences to this behaviour. Snoozing may shorten sleep, compared to setting the alarm to a later time and waking up immediately. This may increase the risk for a number of sleep-loss induced negative effects, such as cognitive (Lim & Dinges, 2010; Lowe et al., 2017) and socio-emotional impairments (A. M. Gordon et al., 2021; Konjarski et al., 2018; Palmer & Alfano, 2017). Regardless of whether sleep is shortened, snoozing

Institution where the study was performed Stockholm University.

through intermittent alarms would be expected to fragment sleep. Deficits in cognition and mood comparable to those found after insufficient sleep have been demonstrated following experimental sleep fragmentation using sound stimuli (Martin et al., 1996; Stepanski, 2002). However, these experiments typically fragment a full night of sleep, and it is unknown whether a brief period of sleep fragmentation prior to awakening has similar negative effects.

Alternatively, if the first alarm interrupts slow-wave sleep (SWS; N3) or rapid-eye-movement (REM) sleep, snoozing may allow for the opportunity to reach a lighter sleep stage (N1 or N2) before having to fully wake up. This could make it easier to wake up and diminish the drowsing effects of sleep inertia, the transitioning period from sleep to waking characterised by impaired performance and sleepiness (Hilditch & McHill, 2019; Tassi & Muzet, 2000; Trotti, 2017). In a forced desynchrony study, having less SWS during sleep periods predicted subjective ease of awakening (Åkerstedt et al., 1997), further supporting this notion. Recent research is more agnostic regarding the predictive effects of sleep stage when waking on sleep inertia, indicating that there are several interacting factors that need to be taken into account (Hilditch & McHill, 2019). Using wearable technology, a recent study concluded that sleep architecture was indeed affected by snoozing (Mattingly et al., 2022). However, as wearable technology is not reliable when estimating sleep stages (Chinoy et al., 2021; Grandner et al., 2021), well-controlled studies on snoozing using polysomnography (PSG) to determine sleep architecture are still needed.

One way of assessing the characteristics of waking up is through the cortisol awakening response (CAR), a sharp increase in cortisol occurring approximately 30–45 min after waking (Clow et al., 2010; Pruessner et al., 1997). Lower levels of cortisol immediately upon waking and 15 min later is associated with higher levels of sleepiness (Dahlgren et al., 2009), whereas a stronger CAR may be related to improved morning alertness and executive functioning (Elder et al., 2014; Law et al., 2015). If a person was allowed to snooze during the 30 min of cortisol increase and get up at its peak, they may feel less sleepy and have better executive functioning when they actually get out of bed.

Through two studies, we aimed to learn more about snoozing behaviour and its effects. In Study 1, we focused on the characteristics of people who snooze and why they choose to delay their waking in this way. As the previous study on snoozing focused on a limited sample (Mattingly et al., 2022), we aimed to include respondents of different ages and from different walks of life. We invited people to respond to an online questionnaire about their sleep and waking habits, specifically focusing on differences between those who reported snoozing at least sometimes and those who reported never snoozing. In Study 2, we used an experimental approach to explore the acute effects of snoozing on sleep architecture, sleepiness, cognitive ability, mood, and CAR. Measuring within-subjects differences between snoozing and not snoozing at final waking, 40 min later, and throughout the day enabled us to assess the effect of snoozing behaviour on sleep inertia as well as daytime functioning.

2 | STUDY 1: SNOOZING BEHAVIOUR

2.1 | Methods Study 1

2.1.1 | Participants

Information and a Qualtrics link to a 'Questionnaire on sleep- and waking habits' was spread among the authors' and their students' networks, e.g., through emails, and posts on social media and student information boards. Participants were informed before starting the questionnaire that participation was voluntary, their responses were anonymous, and they could stop participating at any time. The questionnaire was available in English or Swedish and there were no exclusion criteria. A total of 1732 individuals responded to the survey. The mean (SD) age of respondents was 34 (14) years, although 241 individuals (14%) chose not to report their age. In all, 66% were women and 33% men, with 1% responding 'other' or giving no response to the question of gender. The majority of respondents were from Sweden (80%), followed by the USA (8%), and Finland, the UK, and Australia (3% each).

2.1.2 | Procedure

Following the informed consent, participants answered the questions in Table S1. Only those who reported not using an alarm to wake up in the morning ($N = 250$) were asked about why they did not use an alarm (see supplement for responses). Only those who reported using the snooze function or setting multiple alarms 'sometimes' or more often ($N = 1195$) were asked further questions about their snoozing habits.

2.1.3 | Analysis

To characterise the differences between those who reported snoozing at least sometimes and those who did not, we ran *t* tests or chi-square tests (depending on the outcome variable being continuous or categorical, respectively) comparing snoozers to never-snoozers regarding sleep duration, chronotype, age, and mental drowsiness upon waking. The responses to why participants snoozed were categorised by TS and separately confirmed by JA. The categories were created based on the responses; if a response was given more than once it was made into a category. Each answer could fit into more than one category and each respondent could report more than one reason. For examples of responses for each category, see Table S2. Analyses were conducted using RStudio version 1.4.1106 (RStudio Team, 2021). Data are available from the corresponding author upon reasonable request.

2.2 | Results Study 1

A total of 1195 respondents (69%) reported using the snooze function or setting multiple alarms at least 'sometimes'. Those who reported

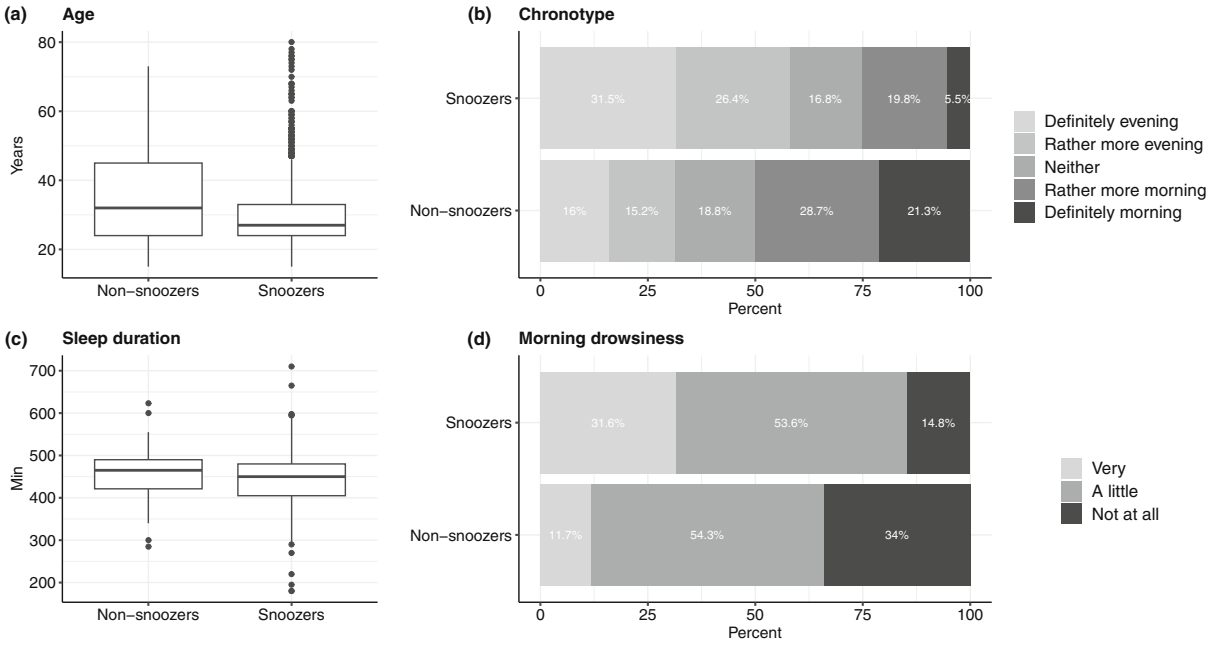

FIGURE 1 Differences between those reporting snoozing at least sometimes and those reporting never snoozing. (a) Boxplot (minimum, first quartile, median, third quartile, maximum) of the age of snoozers (mean [SD] 30 [11] years) and non-snoozers (mean [SD] 36 [14] years). (b) The distribution of chronotypes among snoozers and non-snoozers. (c) Boxplot (minimum, first quartile, median, third quartile, maximum) of self-reported sleep duration on workdays in snoozers (mean [SD] sleep length 7 h 25 min [1 h 10 min]) and non-snoozers (mean [SD] sleep length 7 h 38 min [56 min]). (d) Distribution of reports of mental drowsiness upon morning waking in snoozers and non-snoozers. $N = 1482$.

any amount of snoozing generally snooze on workdays (71%) or both workdays and days off (23%), and 60% report falling asleep between the alarms 'most often' or 'always'. In those who engaged in snoozing behaviour, the mean (SD, range) time spent snoozing per morning was 22 (17, 1–180) min. The mean (SD, range) interval between each alarm was 8 (5, 1–60) min.

Group comparisons were made between those who reported snoozing ($n = 1195$) compared to those who reported using an alarm but 'never' snoozing ($n = 287$; see supplement for comparison between those who reported using an alarm but never snoozing and those who reported not using an alarm). Snoozers were on average 6 years younger than non-snoozers ($t[308] = 6.0$, 95% confidence interval [CI] 3.9–7.7; $p < 0.001$; Figure 1a), and almost four times more likely to be evening types (odds ratio [OR] 3.7, 95% CI 2.7–4.9; $p < 0.001$; Figure 1b). Snoozers also had a slightly shorter sleep duration on workdays, 13 min less on average, compared to those who never snooze ($t[197] = 2.0$, 95% CI 0.13–26; $p = 0.048$; Figure 1c). There was no difference in sleep duration on days off ($t[168] = -1.0$, 95% CI −22.9 to 7.5; $p = 0.320$). While there was no difference in reported sleep quality ($\chi^2 = 3.58$, $p = 0.456$), those who snoozed were three times more likely to feel mentally drowsy upon waking (OR 3.0, 95% CI 2.2–4.0; $p < 0.001$; Figure 1d). Females were not significantly more likely to snooze than males (OR 1.3, 95% CI 1.0–1.7; $p = 0.071$).

The most commonly reported reason for snoozing was 'feeling too tired to wake up' (25% of all snoozers mentioned this), followed by 'it feels good' (17%), and wanting 'to wake up more slowly/softly' (17%). See Figure 2 for all given reasons.

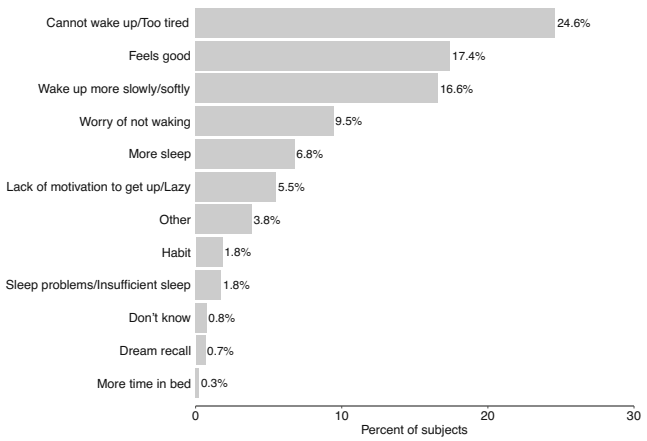

FIGURE 2 Reasons for snoozing. Percentage of subjects mentioning the most common reasons. Note that a respondent could give more than one reason. $N = 1195$.

3 | STUDY 2: SHORT-TERM EFFECTS OF SNOOZING

3.1 | Methods Study 2

3.1.1 | Participants

We recruited 40 habitual snoozers (mean [SD] age 26.7 [6.4] years; 21 women) to take part in this counterbalanced cross-over study. Due

to technical and protocol-adherence issues (see below for details), the final sample consisted of 31 individuals (mean [SD] age 27.5 [6.7] years; 18 women). We did not perform a power analysis; the sample size was determined by resource limitations. Participants all reported during screening that they (1) snooze (i.e., let the alarm go off several times) two or more times per week, and (2) 'always' or 'almost always' fall back asleep between the alarms. Other exclusion criteria were self-reported poor sleep quality, finding it difficult to sleep in other places than one's own bed, having insomnia symptoms such as difficulties falling asleep and waking up often without being able to go back to sleep, heavy snoring, or having current physical or mental health problems. Further exclusion criteria were heavy consumption of alcohol or drugs. Participants were screened for sleep disorders (sleep apnea, periodic limb movements) using PSG during a habituation night at the laboratory. Participants signed an informed consent before taking part in the study. The protocol was approved by the regional ethical review board in Stockholm (dnr: 2016/193 and 2018/2196-32).

3.1.2 | Procedure

All participants slept in the laboratory wearing PSG for 3 nights. During the first, habituation, night they practiced the tests and the procedure in order to reduce potential practice effects during the study. Following inclusion, they slept 2 more nights in the laboratory with two waking conditions in a counter-balanced order: snooze or no snooze. The median time between the two conditions was 7 days, ranging from 2 days to 2 months. Participants kept their habitual sleep time on both occasions, but either slept through the entire night and were awakened by their alarm at their habitual final wake time (sleep-through condition) or 30 min before their habitual wake time, hitting snooze every 9–10 min (snooze condition) until final wakening. In the snooze condition, participants set their alarm on their own mobile phone for 30 min before they had to get up and were instructed to snooze three times before final waking. In the nosnooze condition, participants set their alarm for when they had to get up (i.e., final waking) and were not allowed to snooze. The time of the final waking was the same between conditions, so that participants were in bed with the lights out for the same duration in both conditions.

Immediately on final waking (mean [SD] clock time 7:12 a.m. [46 min]), the ceiling light was turned on, and participants provided a saliva sample and underwent cognitive testing using the Karolinska WakeApp (KWA; Holding et al., 2021). They also rated their sleepiness, effort, and performance after each cognitive test, and finally their mood. This procedure was repeated 40 min later (mean [SD] clock time 7:55 a.m. [46 min]), after which they were given breakfast and left the laboratory. Between final waking and the second test session they were free to move around and take a shower, pack up their things, and talk to the research assistants. The KWA tests and sleepiness and mood ratings were also repeated on the participants' own smartphones around lunchtime (mean [SD] clock time 12:28 p.m. [42 min]) and in the afternoon (mean [SD] clock time 3:50 p.m. [86 min]). There were no restrictions on coffee once participants had left the laboratory.

Participants were not instructed to adhere to a specific sleep–wake protocol before coming to the laboratory for the test nights. The sleep protocol in the laboratory was adjusted to fit their reported habitual sleep and wake times.

3.1.3 | The KWA tests

The test session consisted of four cognitive tests, each lasting ~3 min. They assessed participants' processing speed, episodic memory, and executive functioning. The total test time (including post-test ratings) lasted for a mean (SD) of 13 (2.5) min. These tests are sensitive to sleep loss (Holding et al., 2021) and the arithmetic addition (Wertz et al., 2006) and Stroop (Burke et al., 2015) tests have been shown to be sensitive to sleep inertia. Due to an error, there was some variability in the order of tests in the test battery, with 26 participants having the following order: arithmetic addition, episodic memory, working memory, Stroop. Four participants instead did the tests in the order arithmetic addition, working memory, episodic memory, Stroop. The remaining seven participants completed were given the tests in random order. Due to a technical error, data for one participant was not saved.

Arithmetic addition

For 3 min participants were presented with simple additions of two numbers between 11 and 99 (e.g., '97 + 14') and asked to respond with the correct answer. They were instructed to be as fast and correct as possible. The outcome measure was the time it took them on average for each correct answer, i.e., if they had 13 correct answers, their result would be 180/13.

Episodic memory

Participants were presented with a list of 12 words for 12 s and instructed to memorise them. Following a 5-s fixation cross, they were presented with 24 words, out of which 12 were the same as in the first list and 12 were new. They were instructed to indicate for each word whether it had been on the first list or not. After having responded to all 24 words, they were presented with the first list of 12 words again for 12 s. Following a 5-s fixation cross, these same 12 words were presented along with 12 new words, and participants again indicated for each whether it had been on the memorisation list or not. The outcome measure was the percentage of correct responses for all 48 word presentations.

Stroop

Based on the Stroop colour-word test (Stroop, 1935), this 3-min test showed a colour word (e.g., 'blue'), which was written either in a congruent font colour (i.e., blue) or an incongruent font colour (e.g., red). The participant's task was to indicate the font colour of the word by pressing one of four buttons representing each of the four possible colours (blue, red, green, yellow). The reaction time difference between congruent trials and incongruent trials was measured, as well as the difference between congruent trials and directly subsequent incongruent trials compared to congruent trials followed by congruent trials (for cognitive cost), and the difference between the first incongruent trial and a directly subsequent incongruent trial

compared to a congruent trial followed by an incongruent trial (for behavioural adjustment).

Working memory

Participants were presented with a 4 × 4 grid where squares would briefly flash red, one by one in a random order. Once seven grids had flashed red, one grid turned red and showed a number, e.g., 4. Participants were then to answer whether that particular grid was the fourth grid to flash red in the just-viewed session. The outcome measure was the percentage of correct answers out of the 18 rounds presented.

3.1.4 | Post-test ratings

After each test, participants rated their sleepiness, performance, and effort during the test. Sleepiness was rated using the Karolinska Sleepiness Scale (Åkerstedt & Gillberg, 1990), which is a 9-point scale asking 'How sleepy are you right now?' with response options ranging from 1 = 'Extremely alert' to 9 = 'Very sleepy'. We also asked participants how much effort they put into each test, as well as how they thought the performed, on 9-point scales ranging from 1 = 'Very little/poorly' to 9 = 'Very much/well'.

3.1.5 | Mood ratings

Mood was assessed using a subset of the questions in Haack & Mullington (2005), focusing on optimism-sociability, tiredness-fatigue, and anger-aggression (specifically bad tempered and bewildered). The questions were phrased as 'Right now, do you feel ___?', for each of the following words: friendly, drowsy, optimistic, efficient, bewildered, considerate, sociable, cheerful, sluggish, worn out, bad tempered. As in the original study, these were responded to on a 0–100 visual analogue scale, with the end points 0 = 'Not at all' and 100 = 'Very'.

3.1.6 | Cortisol awakening response

Cortisol was collected directly upon final waking as well as 40 min later using saliva Salivettes; all samples taken before breakfast. After collection, saliva samples were directly frozen in a −75°C freezer, and at the end of the study samples were analysed in duplicates by the Kirschbaum laboratory Technische Universität Dresden, Germany using a commercially available chemiluminescence immunoassay with high sensitivity (IBL International, Hamburg, Germany). Samples from each subject were stored and analysed together. The intra- and inter-assay coefficients were <8%.

3.1.7 | Polysomnography

The PSG recordings were acquired using a Vitaport 3 (TEMEC Technologies, Heerlen, the Netherlands). The PSG montage followed the 10–20 system and included electroencephalography (C3, C4, F4, O2, M1, M2), bi-lateral electro-oculography (E1, E2), chin electromyography, and electrocardiography, all sampled at 256 Hz. On the screening night, oxygen saturation was measured via finger-tip oximetry. Leg movements were assessed by anterior tibialis electromyography. Sleep stages and arousal were scored according to standard criteria (Berry et al., 2017). Hypopnea events were scored according to the American Academy of Sleep Medicine (AASM) 2012 recommended criteria. Participants were excluded if they had an apnea-hypopnoea index of >15 events/h or a periodic leg movement index of >15/h, resulting in one potential participant being excluded. PSGs were scored in Profusion Sleep 4 (Compumedics, Melbourne, Australia) by an experienced sleep technologist blinded to both condition and the timing of the snooze period.

3.1.8 | Analyses and data loss

For effects of snoozing on sleep architecture, paired samples *t* tests or Wilcoxon signed-rank tests (depending on normality of data, based on Shapiro–Wilk tests and q–q plots), as well as Bayesian *t* tests using the presets in JASP (JASP Team, 2023) were used to compare differences in sleep between conditions. Analyses were performed across the full night, as well as separately for the 30 min before final waking, i.e., the specific time when participants did or did not snooze. As participants were not disturbed in their rooms during the night, we used the PSG recordings to ensure that the snooze protocol had been adhered to. We thus excluded participants who, e.g., woke up before their alarms in either condition, or for whom the snooze condition for either night or both nights could not be confirmed. Out of the original 40 participants, nine were excluded based on the PSG recordings (affecting 7 snooze nights and 3 sleep-through nights, i.e. one participant had both nights affected). Out of these 10 nights, two had PSG file recording issues, four encountered significant signal loss during the snooze period such that sleep staging could not be accurately performed. Finally, for 4 nights the PSG recording showed that the participant woke earlier than the snooze period was scheduled to begin and achieved no additional sleep for the rest of the time.

To assess the effects of snoozing and sleep inertia, we used linear mixed models with condition (snooze versus no snooze), time (final waking versus 40 min later), and their interaction as fixed effects, allowing for random intercepts for subjects. We ran separate models for each of the outcome measures, that is the four cognitive tests, ratings of sleepiness, effort, performance, and mood, and cortisol levels. We further ran Bayesian mixed-model analyses, comparing the model with time awake to an intercept-only model, and then the model also including snooze and the model also including the interaction with each simpler model. Prior to each analysis, test performance, cortisol levels, or ratings above or below 3 SDs of the mean were excluded. For the Stroop task, responses faster than 250 ms were removed (Parris, 2014). For one participant, none of the test sessions were saved, and for Stroop, one participant was excluded due to misunderstanding the instructions. This means that $n = 30$ for all cognitive

TABLE 1 Sleep architecture in snooze and sleep-through conditions for the whole night and final 30 min before waking.

	Whole night				Final 30 min before waking			
Variable	Sleep-through	Snooze	*p*	BF_{10}	Sleep-through, median (IQR)	Snooze, median (IQR)	*p*	BF_{10}
TIB, min, mean (SD)	466.9 (37.3)	469.9 (38.2)	0.196	0.422	30.0 (30.0–30.5)	30.0 (30.0–30.5)	1	0.202
TST, min, mean (SD)	416.6 (53.3)	418.0 (43.8)	0.805	0.197	29.0 (28.0–30.0)	23.0 (15.0–26.5)	**<0.001**	**6430**
SOL, min, median (IQR)	15.0 (9.0–30.0)	22.0 (11.0–31.5)	0.079	1.778				
WASO, min, median (IQR)	20.5 (10.5–30.5)	20.0 (13.0–36.0)	0.388	0.221	0.5 (0.0–1.5)	2.5 (1.5–4.0)	**<0.001**	**1089**
SE, %, median (IQR)	90.2 (86.2–94.6)	90.8 (86.3–93.4)	0.394	0.249	95.1 (93.3–100)	75.4 (50.8–88.3)	**<0.001**	**1751**
NREM, min, mean (SD)	326.5 (44.0)	333.6 (32.0)	0.232	0.377	18.0 (9.5–29.5)	18.5 (11.5–24.0)	0.616	0.227
N1, min, median (IQR)	20.5 (14.5–32.0)	19.5 (12.0–33.0)	0.104	0.370	1.0 (0.5–2.5)	4.0 (1.5–6.0)	**<0.001**	**2599**
N2, min, mean (SD)	206.9 (35.6)	212.2 (29.6)	0.362	0.284	11.5 (5.5–23.5)	13.5 (7.0–20.5)	0.845	0.204
N3, min, mean (SD)	95.4 (27.5)	98.0 (28.3)	0.617	0.216	0.0 (0.0–2.0)	0.0 (0.0–0.0)	**0.005**	**N/A**[a]
REM, min, mean (SD)	90.1 (28.5)	84.7 (22.8)	0.263	0.346	4.5 (0.0–16.5)	0.0 (0.0–4.5)	**0.004**	**8.089**
Arousals/h, median (IQR)	5.6 (3.9–8.3)	5.6 (4.0–7.1)	0.894	0.196	2.1 (0.0–4.3)	5.0 (2.1–14.1)	**0.002**	**48.24**

Note: Statistics are reported as mean (standard deviation; SD) normally distributed values, or median (interquartile range [IQR]) for non-normal distributions. Bold values statistically significant at $p < 0.05$.

Abbreviations: BF_{10}, Bayes factor; NREM, non-rapid eye movement sleep; REM, rapid eye movement; SE, sleep efficiency; SOL, sleep onset latency; TIB, time in bed; TST, total sleep time; WASO, wake after sleep onset.

[a]As there was no variance in the snooze condition for N3 in the final 30 min before waking, a Bayes factor could not be calculated.

tasks and ratings other than Stroop, where $n = 29$. Due to a programming error, four participants performed a shorter version of the working memory task (six rounds instead of 18). For cortisol, two participants did not produce enough saliva for analysis, resulting in a final $n = 28$. In addition, one participant did not produce enough saliva for the first session in the sleep-through condition, and three participants did not produce enough saliva for the second session in the sleep-through condition.

For the lunch and afternoon tests and ratings, we ran paired *t* tests or separate mixed models for each session and outcome with condition (snooze versus no snooze) as the fixed factor and subject as a random factor, allowing for random intercepts (see supplement).

Analyses were conducted using RStudio version 1.4.1106 (RStudio Team, 2021), using the 'lmer' function in the 'lme4' package (Bates et al., 2015) for the linear mixed models, and the 'lmBF' function in the 'BayesFactor' package (Morey R, 2022) for the Bayes factors. Bayes factors are presented as BF_{10}, i.e., higher numbers indicate that the alternative hypothesis is more likely. For interpretation of the Bayes factors, we used a slight modification of Jeffreys (1961), as reported in (Andraszewicz et al., 2015). Briefly, any BF_{10} of >3 was interpreted as support for the alternative hypothesis, whereas BF_{10} of <0.33 was interpreted as support for the null hypothesis, and a value between 0.33 and 3 was interpreted as inconclusive. All tests were exploratory, and the outcomes were not adjusted for multiple comparisons. Data are available from the corresponding author upon reasonable request.

3.2 | Results Study 2

3.2.1 | Sleep architecture

For the whole night sleep period, including the last 30 min, there were no significant sleep architecture differences between the conditions (see Table 1). Although the Bayes factors indicate that the results are inconclusive regarding differences between conditions for time in bed, sleep onset latency, NREM, N1 and REM, these differences were small (≤7 min across the whole night). During the 30 min prior to final waking, snoozing induced a number of sleep architecture changes compared to the sleep-through condition (Table 1). Participants in the snooze condition had less sleep time, more arousals, and lower sleep efficiency during this time. Snoozing was also associated with more stage N1 sleep and less REM sleep. The evidence for these differences is generally robust, as indicated by the Bayes factors. Notably, no participant had any SWS (N3) in the snooze condition, while 30% (10/31) had at least some N3 sleep in the 30 min prior to waking in the sleep-through condition (Figure 3). In all, the 30-min snooze period was characterised by brief awakenings and a considerable amount of sleep, ~23 min. This sleep included very little REM sleep and no N3. In both conditions, the majority of participants' final awakening occurred following N2 sleep (snooze; $n = 23$; sleep through, $n = 19$). Awakenings from REM were rarer (snooze, $n = 6$; sleep through $n = 10$), and only two participants had a final awakening from deep (N3) sleep (both during sleep-through

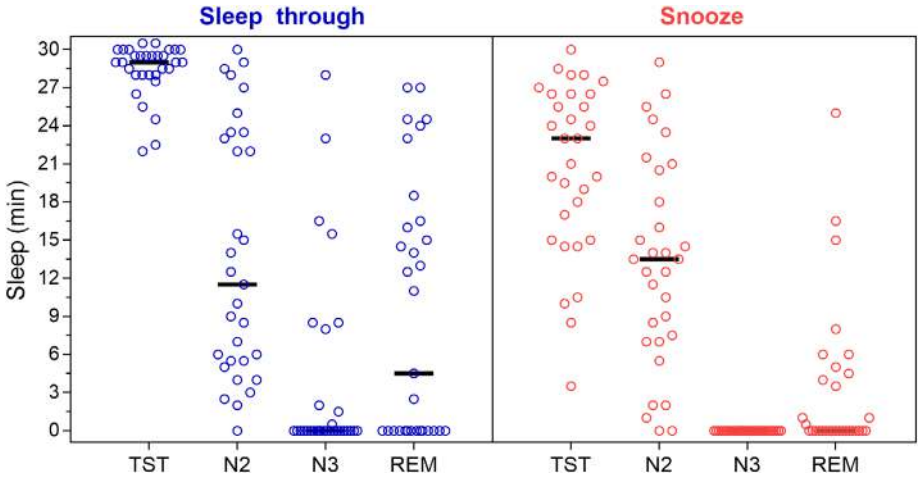

FIGURE 3 Distribution of minutes spent in different sleep stages in the snooze and sleep-through conditions. Circles represent individual data showing the time spent in each sleep stage over the 30 min prior to final awakening. Blue circles represent the condition in which people slept through this entire period whereas red circles show the condition in which participants snoozed during this period. The black lines represent medians. NREM, non-rapid eye movement sleep; REM, rapid-eye-movement sleep; TST, total sleep time. $N = 31$.

condition). Similarly, only two participants woke following N1 sleep (both during snooze condition).

3.2.2 | Cognitive functioning

Participants ($n = 30$) completed a cognitive test battery directly upon final awakening and 40 min later, assessing arithmetic speed, episodic memory, working memory, and cognitive conflict processing (Stroop test). Performance on all tasks, except the Stroop test, showed an inertia effect, such that performance improved with time awake (Table 2). In the snooze condition, this inertia was reduced, with participants performing better on arithmetic speed, episodic memory, and cognitive conflict cost (i.e., the extra cost in processing time for the first incongruent trial after a congruent trial in the Stroop test). The interaction effect between time awake and condition for episodic memory indicates that the positive effect of snoozing disappeared after 40 min (Table 2 and Figure 4) There were no differences between the two conditions on working memory, or behavioural adjustment in the Stroop test (i.e., the difference in reaction time between incongruent trials following congruent trials and those following incongruent trials). There were no additional interaction effects between condition and time awake for any of the tasks or ratings, indicating that there was some sleep inertia both in the sleep-through condition and the snooze condition. The Bayes factors suggest that more data are needed in order to draw reliable conclusions for virtually all of the above effects (Table 2). Only for the effects of time awake on arithmetic speed and general reaction time on the Stroop test, and the interaction effect on episodic memory, were the Bayes factors large enough to indicate moderate to strong evidence against the null hypotheses. For the effect of snoozing on cognitive conflict cost, the Bayes factor is more in line with the evidence pointing to a null effect.

3.2.3 | Cortisol levels

As shown in Figure 4e and Table 2, cortisol levels increased with time awake, indicating a CAR across both conditions. While there was no main effect of snoozing nor a clear interaction effect between snoozing and time awake, exploratory t tests showed that cortisol levels were higher at waking in the snooze condition compared to in the sleep-through condition (+1.8 nmol/dl, 95% CI 0.3–3.3; $t[26] = 2.4$, $d = 0.38$, $p = 0.024$), but not 40 min post waking (−0.9 nmol/dl, 95% CI −1.0 to 2.9; $t(24) = 0.97$, $d = 0.15$, $p = 0.341$). The associated Bayes Factors indicate that while the evidence for an effect of time awake and a null effect of snoozing was strong, more data is needed before drawing conclusions about the interaction effect.

3.2.4 | Ratings of sleepiness, performance, effort, and mood

Ratings of sleepiness and task-related performance both clearly improved between final awakening and 40 min later, again indicating an effect of sleep inertia. Task-related effort was unaffected by time awake. There were no effects of snooze condition nor interaction effects between condition and time awake for any of these ratings (Table 2 and Figure 5a–c). The Bayes factors mostly support these conclusions, with the exception of the effect of snoozing on task-related performance where the findings are inconclusive.

Mood ratings also showed a clear improvement with time awake, with participants reporting feeling more sociable and optimistic, less fatigued, and less bewildered and bad tempered 40 min after waking compared to directly after waking (Table 2 and Figure 5d–f). There was no effect of snooze condition for any of the mood ratings, nor an interaction effect between condition and time awake. The Bayes factors generally indicate that the evidence is strong for these findings.

3.2.5 | Relationship between sleep architecture and cognitive task performance

Exploratory correlational analyses were performed to examine the relationship between differences in sleep characteristics between the snooze and no snooze condition verses the snooze-related

TABLE 2 Effects of time after waking and snoozing on cognition, cortisol, and subjective dimensions.

Variable	Intercept[a]	95% CI (lower; upper)	Time awake	95% CI (lower; upper)	*p*	BF_{10}	Snooze	95% CI (lower; upper)	*p*	BF_{10}	Interaction	95% CI (lower; upper)	*p*	BF_{10}
Arithmetic speed, s	9.0	8.0; 10.0	−1.6	−2.3; −8.0	**<0.001**	**1432**	−0.8	−1.6; −0.5	**0.042**	**1.52**	0.5	−0.6; 1.5	0.411	0.34
Episodic memory, % correct	89.5	87.4; 91.6	3.7	1.5; 5.9	**0.002**	**0.96**	3.4	0.4; 4.7	**0.003**	**0.91**	−4.2	1.5; 5.9	**0.012**	**5.60**
Working memory, % correct	77.0	72.5; 81.6	6.7	1.7; 11.7	**0.011**	**1.17**	−0.9	−4.1; 5.9	0.734	0.48	−6.1	−13.2; 1.0	0.100	1.13
Executive function (Stroop)														
Reaction time, ms	1300	1237; 1362	−90	−112; −67	**<0.001**	**5.1×10^{52}**	−4	−27; 18	0.700	0.03	−2	−33; 29	0.898	0.05
Trial congruency[a], ms	−152	−177; −67	−3	−37; 30	0.849	0.06	16	−18; 50	0.357	0.06	−13	−60; 33	0.575	0.05
Cognitive conflict cost, ms	193	155; 231	−2	−45; 31	0.93	0.10	−45	−89; −1.6	**0.043**	**0.24**	39	−20; 98	0.199	0.20
Behavioural adjustment, ms	−3	−51; 44	−33	−94; 28	0.285	0.11	9	−52; 70	0.782	0.08	12	−72; 97	0.775	0.10
Ratings														
Sleepiness (1–9)	6.5	5.8; 6.7	−1.4	−1.7; −1.0	**<0.001**	**1.1×10^{27}**	<0.1	−0.3; 0.5	0.771	0.10	−0.2	−0.7; 0.3	0.380	0.16
Task-related performance (1–9)	5.4	4.9; 5.9	0.5	0.1; 0.8	**0.016**	**28**	−0.2	−0.6; 0.1	0.227	0.64	<−0.1	−0.5; 0.5	0.961	0.18
Task-related effort (1–9)	6.7	6.2; 7.1	<−0.1	−0.3; 0.2	0.857	0.11	<0.1	−0.3; 0.3	0.962	0.19	0.1	−0.3; 0.5	0.579	0.23
Sociability-optimism (VAS 0–100)	42.3	37.6; 47.1	16.6	11.1; 22.1	**<0.001**	**7.9×10^{9}**	−1.6	−7.0; 3.9	0.578	0.23	−0.7	−8.4; 7.0	0.858	0.18
Tiredness-fatigue (VAS 0–100)	63.6	56.7; 70.4	−18.5	−25.6; −11.4	**<0.001**	**3.7×10^{7}**	1.0	−6.1; 8.0	0.792	0.18	0.8	−9.2; 10.8	0.877	0.21
Bad tempered-bewildered (VAS 0–100)	44.2	37.0; 51.3	−15.7	−22.7; −8.7	**<0.001**	**1.9×10^{5}**	−0.9	−7.9; 6.0	0.798	0.18	1.7	−8.2; 11.6	0.737	0.25
Cortisol, nmol/dl	6.6	4.6; 8.6	6.7	4.5; 8.9	**<0.001**	**1.9×10^{6}**	1.8	−0.3; 4.0	0.097	0.19	−3.1	−6.1; −0.0	0.054	1.30

Note: Main effects (*b*), 95% confidence interval (CI), *p* values, and Bayes factors (BF_{10}) of time awake and snooze condition, and the interaction between time awake and condition, from the linear mixed model. Arithmetic speed is the time in seconds per correct response, episodic memory and working memory are percentage correct responses. Executive function is reaction time in milliseconds. Sleepiness, task-related performance, and task-related effort are ratings on a scale from 1 = 'Very sleepy/poorly/little' to 9 = 'Very alert/well/much', respectively. Sociability-optimism, tiredness-fatigue, and bad tempered-bewildered are rated on visual analogue scales (VAS) ranging from 0 = 'Not at all' to 100 = 'Very'. Bold values statistically significant at $p < 0.05$.

[a]For trial congruency, the effects reported are interactions between trial congruency and the mentioned factor. The intercept column for trial congruency thus represents the main effect of congruency in the full model rather than an intercept, and the Interaction column represents a three-way interaction between trial congruency, time awake, and snooze condition.

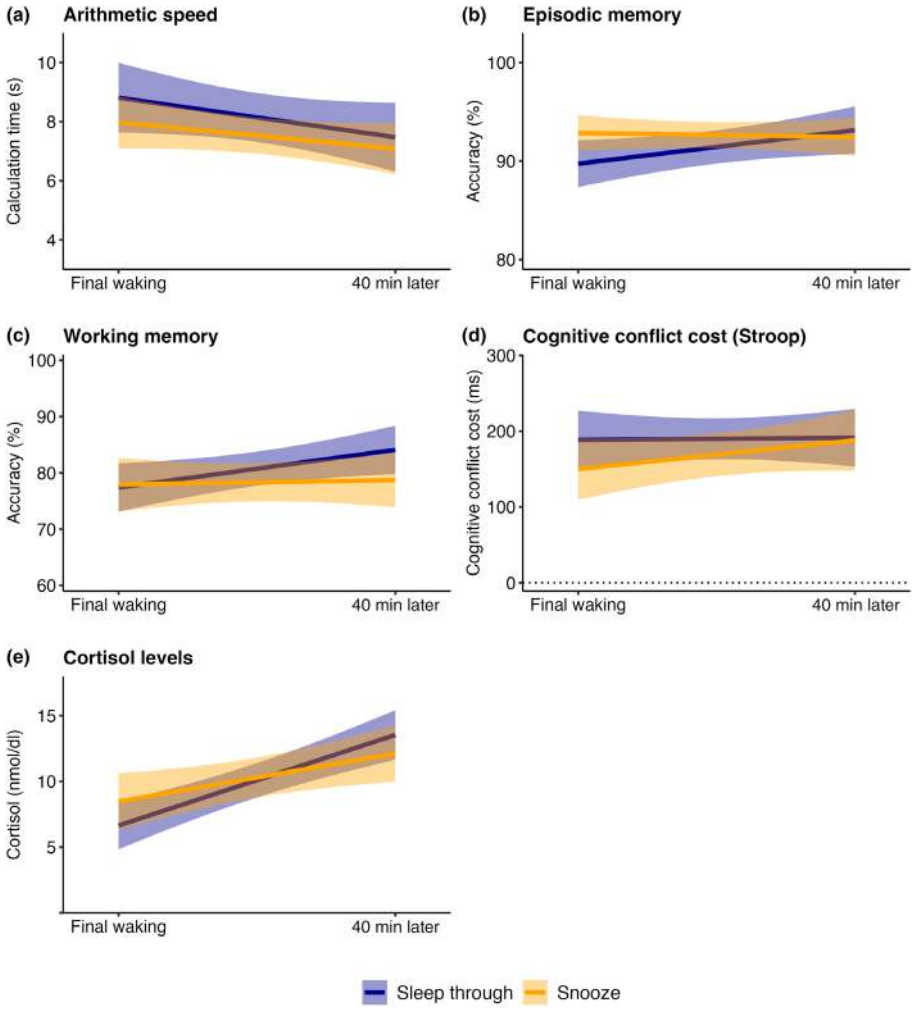

FIGURE 4 Cognitive functioning and cortisol levels in snooze and sleep-through conditions. The test battery was carried out immediately upon waking and 40 min after awakening. Participants in the snooze condition performed better on all cognitive tasks except for working memory. For episodic memory, the benefit of snoozing disappeared after 40 min. The effect of snooze condition on CAR was inconclusive. Cortisol levels and performance on all tasks, except for Stroop, increased with time awake. (a) total time divided by the number of correct arithmetic calculations (s), (b) episodic memory accuracy (% words remembered correctly) (c) working memory accuracy (% correct responses), (d) cognitive conflict costs on the Stroop task (reaction time difference in ms for first incongruent trial compared to preceding congruent trial). A higher number indicates a larger cognitive conflict. (e) salivary cortisol levels in nmol/dl.

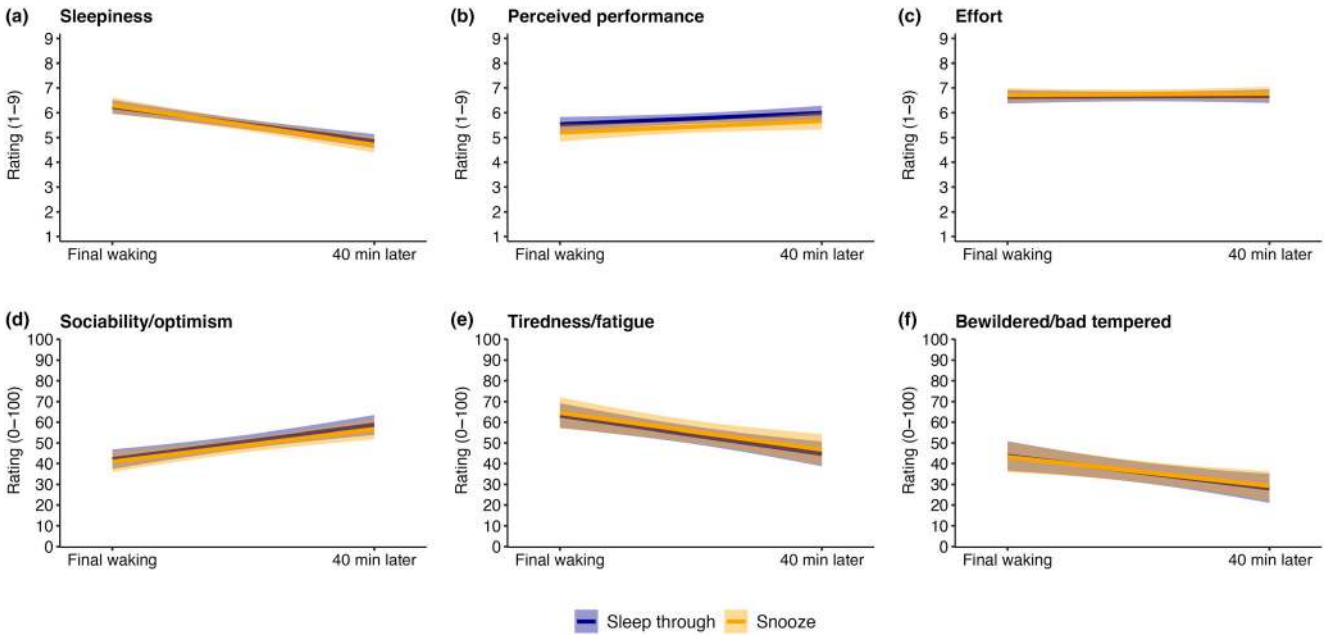

FIGURE 5 Effect of snooze condition and time awake on ratings of sleepiness, performance, and effort in relation to the cognitive tasks. The lines were fitted through mixed linear models, indicating no effect of snooze condition or interaction of condition and time awake on any of the ratings. All ratings except for task-related effort improved after 40 min awake.

performance benefits noted for arithmetic speed, episodic memory, and conflict cost (i.e., Δsleep versus Δcognitive task performance). There was a moderate association ($r = 0.44$, $p = 0.023$) between a better arithmetic performance and a longer sleep time during the snooze period. All other relationships were weak and not statistically significant (supplement Figures S3–S5).

3.2.6 | Daytime effects

There were no substantial effects of morning snoozing on cognitive performance during lunchtime or in the afternoon (Tables S3 and S4). However, participants in the snooze condition reported feeling slightly sleepier during lunchtime and putting in more effort during the tests in the afternoon, compared to the sleep-through condition. There were no effects of snoozing on sleepiness in the afternoon, nor on ratings of performance during the cognitive tests, nor mood in any of the daytime measures (Tables S3 and S4).

4 | DISCUSSION

The findings demonstrate that snoozing is a common behaviour, which is in line with previous surveys showing that many people snooze at least sometimes (Mattingly et al., 2022; Roitmann, 2017). Although one could argue that the snooze period would be better spent sleeping, considering the detrimental effects of reduced and fragmented sleep (Lim & Dinges, 2010; Lowe et al., 2017; Martin et al., 1996; Stepanski, 2002), snoozing appears to serve a function for those who engage in this behaviour. Regular snoozers tend to feel more mentally drowsy upon waking, which goes along with the finding that they are younger and later chronotypes than those who never snooze. These individuals may need more time to ward off the effects of sleep inertia, and snoozing may be a potential way of doing this, considering the cognitive improvements seen in Study 2. Even though participants felt equally sleepy upon waking in both conditions, they performed better on three out of the four cognitive tests at final waking when they had been allowed 30 min of snoozing beforehand. Although more evidence is needed to support this finding of improvements in cognitive function, it is at least clear that snoozing does not lead to cognitive impairments upon waking in habitual snoozers.

In addition, the snoozing condition still allowed for comparable sleep across the whole night, while preventing final awakening from SWS (N3). Indeed, in almost all cases, snoozing meant that the final awakening occurred from light sleep (N1 or N2), limiting the likelihood of having to rise from SWS and experiencing more severe sleep inertia (Hilditch & McHill, 2019; Tassi & Muzet, 2000). In the snooze condition, none of the participants had any SWS in the 30 min before final awakening, whereas 30% (10 participants) had SWS in the sleep-through condition. The fact that about a third of the subjects had SWS in the 30 min prior to waking in the sleep-through condition raises an interesting possibility; individuals with more SWS close to rising may be more likely to become snoozers, as a way to reduce the likelihood of having to rise directly from this sleep stage.

It is not surprising that most snoozers are young, considering that population studies show that 42% of adolescents have difficulties waking up from sleep (Amaral et al., 2014), a proportion that is gradually reduced with age (Ohayon et al., 2000). Adolescence through the early twenties is also when one's chronotype tends to be at its latest (Fischer et al., 2017; Roenneberg et al., 2004), which in combination with early morning school or work increases the risk of reduced sleep and drowsy mornings (Lack et al., 2009; Roepke & Duffy, 2010). As chronotype and amount of SWS negatively predicts subjective ease of wakening (Åkerstedt et al., 1997), late chronotypes would be expected to suffer from more sleep inertia. This also explains the reports of snoozing due to drowsiness, and in order to wake up more slowly. Virtually every measured aspect, cognitive as well as subjective, in Study 2 improved from final waking to 40 min later, indicating prominent effects of sleep inertia. This could be expected, considering that the participants were habitual snoozers and, as indicated by Study 1, likely to feel mentally drowsy when waking. Although we also found small positive effects of snoozing on cognitive performance for arithmetic speed, episodic memory, and cognitive cost in the Stroop task, only episodic memory showed an interaction effect between time awake and condition. While this suggests that snoozing improves performance for the entire 40-min time period, it is likely that the effects wear off over time awake. The main benefit of snoozing may thus be a reduction of inertia directly upon waking. While the positive effects of snoozing were generally smaller than those of time awake, this is reasonable considering that the impairments caused by inertia can be larger than being awake for 24 h and performing in the middle of the night (Wertz et al., 2006).

There were no clear effects of snoozing on the CAR, but the fact that snoozing resulted in subjects having higher cortisol levels immediately upon waking indicates a slight advance of the onset of the CAR. There is conflicting research regarding whether awakening time, sleep duration, or sleep continuity affect cortisol levels or the CAR (Anderson et al., 2021; Elder et al., 2014, 2016; Lemola et al., 2015; Van Dam et al., 2018), and further studies are needed before we understand the physiology behind problems rising and how to best support the awakening process.

Studies that have experimentally shortened or disrupted/fragmented sleep have shown that participants are sleepier and have worsened cognition and poorer mood the following day (Martin et al., 1996; Stepanski, 2002). In the present study, snoozing was shown to have a disrupting effect on sleep. During the snooze period (30 min before awakening) there were more arousals, poorer sleep efficiency and more light sleep when snoozing compared to the sleep-through condition. However, participants still obtained about 20 min of sleep during this period, and in the context of the total sleep period these differences were small and not statistically significant for any of the PSG outcomes assessed. Introducing a few extra awakenings for 30 min is not likely to have the same effects as regular interruptions across the night, although longer snoozing periods could still cause problems with daytime cognition and mood. In addition, given that

participants slept in a laboratory environment, it is likely that the disrupting effects of snoozing found in our study (e.g., a few of the subjects obtained <10 min of sleep while snoozing) is smaller when snoozing at home. Note however, that for those who are already getting insufficient or disturbed sleep, a 30-min snooze period may be more detrimental than for someone who is sleeping 7–8 h. It is also possible that snooze-related sleep disruptions are accumulated over several days.

A surprising finding was that snoozing did not affect self-reported sleepiness or mood. Considering that the most commonly reported reasons for snoozing in Study 1 included drowsiness and that it feels good, one would have expected a direct effect of being allowed to snooze on these subjective measures. One possibility is that individuals who are very drowsy when the alarm goes off choose to snooze because it is preferable to rising, rather than for its positive effects on sleepiness and mood. Potentially, these individuals will always feel sleepy upon waking, regardless of waking style. However, the results indicate that even though the participants did not report feeling less sleepy or more joyful after snoozing, the slower awakening still improved their cognitive abilities. To our knowledge, this is the first study directly looking at mood during the morning sleep inertia period. There is one previous report of mood effects during night-time sleep inertia, finding that waking from SWS was related to worsened mood compared to pre-sleep (Hilditch et al., 2022). We complement this by showing that optimism/sociability and anger/aggression both improve from waking to 40 min later in this group of habitual snoozers.

There are several limitations to these studies. Study 1 focused on waking preferences in a convenience sample. In order to estimate the prevalence of snoozing, we need studies with representative samples. Study 2 only included habitual snoozers and therefore it is difficult to generalise our findings to individuals who do not usually snooze. It is thus possible that worsened cognition in the no-snooze condition may have resulted from not snoozing for individuals who would usually snooze. Although an optimal study design would be to include a group of non-habitual snoozers, it is not plausible to make someone snooze when they normally wake up fully with the first alarm. Another limitation is that the experimental design assumed that snoozers usually set their alarm earlier than they need to in order to snooze. It is possible that some individuals set their alarm for when they actually want to get up, and then snooze for an additional period of time. Furthermore, we only investigated the effect of 30 min of snoozing. Study 2 was designed to represent one of the most commonly reported snooze times (30 min), but it is possible that longer or shorter snooze times have different effects on sleep inertia, the CAR, subjective sleepiness, and mood. Longer snooze times are also more likely to have a bigger effect on the overall sleep architecture of the night, potentially leading to more sleepiness during the day even if the effects of sleep inertia were to be smaller. Future work could assess the impact of longer snoozing times assessed over several nights as well as focusing on the more long-term impact of snoozing. Although snoozing only had small effects on the whole-night sleep, it still resulted in slightly increased sleepiness and having to use more effort later in the day, effects that may accumulate over time. It would also be interesting to see whether amount of daylight in the morning affects snoozing behaviour, such that season plays a role in whether people choose to snooze or not.

In conclusion, the most commonly reported reason for snoozing is feeling too tired to wake up, indicating sleep inertia. Snoozing for 30 min in the morning before final awakening had only small effects on sleep but prevented having to rise from SWS. While snoozing did not clearly affect subjective sleepiness or mood, it may be beneficial in relieving sleep inertia and improve cognitive functioning right upon waking.

AUTHOR CONTRIBUTIONS

Tina Sundelin: Conceptualization; investigation; funding acquisition; writing – original draft; methodology; validation; visualization; writing – review and editing; formal analysis; project administration; data curation; supervision. **Shane Landry:** Methodology; visualization; writing – review and editing; formal analysis. **John Axelsson:** Investigation; methodology; funding acquisition; resources; supervision; project administration; writing – review and editing.

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CONFLICTS OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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