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ORIGINAL ARTICLE

Snoozing: an examination of a common method of waking

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Abstract

Study Objectives: Snoozing was defined as using multiple alarms to accomplish waking, and considered as a method of sleep inertia reduction that utilizes the stress system. Surveys measured snoozing behavior including who, when, how, and why snoozing occurs. In addition, the physiological effects of snoozing on sleep were examined via wearable sleep staging and heart rate (HR) activity, both over a long time scale, and on the days that it occurs. We aimed to establish snoozing as a construct in need of additional study.

Methods: A novel survey examined snoozing prevalence, how snoozing was accomplished, and explored possible contributors and motivators of snoozing behavior in 450 participants. Trait- and day-level surveys were combined with wearable data to determine if snoozers sleep differently than nonsnoozers, and how snoozers and nonsnoozers differ in other areas, such as personality.

Results: 57% of participants snoozed. Being female, younger, having fewer steps, having lower conscientiousness, having more disturbed sleep, and being a more evening chronotype increased the likelihood of being a snoozer. Snoozers had elevated resting HR and showed lighter sleep before waking. Snoozers did not sleep less than nonsnoozers nor did they feel more sleepiness or nap more often.

Conclusions: Snoozing is a common behavior associated with changes in sleep physiology before waking, both in a trait- and state-dependent manner, and is influenced by demographic and behavioral traits. Additional research is needed, especially in detailing the physiology of snoozing, its impact on health, and its interactions with observational studies of sleep.

Statement of Significance

Snoozing, or using multiple alarms to wake, is virtually unstudied. Snoozing is discouraged by sleep scientists and medical professionals but there is no consensus on why snoozing is bad, nor how often snoozing occurs. Here snoozing is studied in a large population for the first time and it was discovered that >50% of working adults sampled snoozed habitually. Trait constructs such as sex, age, physical activity, and personality were associated with snoozing. Physiological data suggested snoozing could produce short-term waking benefits through elevated HR and lightened sleep, making it easier to wake up in the morning. Given the prevalence of snoozing, it is important to understand how snoozing impacts health and sleep measurement.

Key words: snooze; sleep; wearables; sleep staging; heart rate

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Introduction

"Snoozing" is virtually unstudied and has no agreed upon definition. This paper defined snoozing as waking to an alarm after an initial alarm has already generated some degree of alertness, which allowed us to differentiate between a single alarm and multiple alarms. For example, an individual snoozed if they set alarms for 06:45 am and 07:00 am with the intention of waking at 07:00 am, or if they only set a single alarm at 06:45 am and then used a "snooze button" to disable the alarm and have another one occur a short time after. Although few peer-reviewed articles are published about snoozing or use snoozing as an experimental manipulation (e.g. [1]), popular science, newspaper articles, and health blogs (e.g. [2–6]) suggest that snoozing can have negative health effects from increased stress or from sleep disruption. The lack of snoozing literature suggests that claims about negative health effects should be evaluated. This study examined how stress system activity brought on by snoozing could interrupt sleep and make it easier to eventually wake. Evidence is presented that demonstrates the prevalence of snoozing in our sample and the association of snoozing with several psychological constructs and demographic traits. Additionally, comparisons were conducted on wearable-measured physiology during snoozing and nonsnoozing days. Finally, limitations were stated and future research is suggested.

Sleep inertia

Shorter sleep durations have been associated with numerous trait-like and demographic effects such as age, sex, and chronotype [7–13]. Restricted sleep can lead to many negative effects, such as increased morbidity and mortality [14], and sleep inertia. Sleep inertia is the physiological state in transition from sleep to wake that is marked by decreased alertness, impaired performance (physical, mental), and disorientation [15] which can persist between 21 min [16] and 2 h [15, 17]. Sleep inertia may vary depending on how and when an individual wakes. An idealized nocturnal sleep period can be divided into roughly 90-min sleep cycles that start with a high proportion of deep slow-wave sleep (N3) and a lower proportion of lighter stages of sleep such as N1, N2, and Rapid Eye Movement sleep (stage R). Successive cycles reduce N3 in favor of N1, N2, and stage R. Natural waking generally occurs from N1, N2, or stage R sleep [18] (for a theoretical review, see [19]), culminating in an increase of the stress hormone cortisol, called the cortisol awakening response (CAR). The CAR occurs after natural waking and is theorized to counteract sleep inertia [20, 21]. Other factors that can reduce sleep inertia include waking from lighter sleep such as stage R or N1 [22, 23], consuming caffeine [24, 25], or self-awakening (going to bed with the intention to wake up at a particular time) compared to having an external awakening (e.g. experimenter, alarm) [26]. Of these factors, only self-awakenings have been associated with increased hypothalamic pituitary adrenal axis (HPA) axis activity 60 min before self-awakening (for review, see [27]). Thus, waking naturally after sufficient sleep tends occur from light sleep, especially stage R sleep, is supported by a CAR, and generates low sleep inertia. When sleep is disturbed by an alarm, it is less likely that the individual is waking from light sleep or that they will mount a CAR, increasing the likelihood of sleep inertia. Snoozing may lessen sleep inertia through several mechanisms including repeated alarms with associated stress responses, repeated awakenings that result in lighter sleep before ultimate waking, and/or by mirroring self-awakening by setting a specific intended wake time.

Stress

Stress responses promote alertness and decrease sleepiness and the ability to fall asleep [28, 29]. Stress reactions occur via the quicker sympathetic nervous system (SNS), which results in changes such as increased heart rate (HR), and the slower hypothalamic pituitary adrenal system, which results in increased stress hormone cortisol [30], the same hormone that naturally increases after natural waking. Alarm(s) that can wake individuals evoke a stress response in both systems [31]. For instance, Hall et al. [31] found increased cortisol and HR when participants were awakened during the night with an auditory alarm compared to a gentle awakening. Since snoozing is composed of multiple alarms, and an alarm can invoke a stress response, it is reasonable to assume that snoozing can invoke a stress response. If snoozing invokes a stress response, we would expect HR to be higher in snoozers before and/or upon waking.

Sleep interruptions

The first alarm during snoozing is considered as an interruption, though it is unknown how similar snoozing-based sleep interruptions are with other sleep interruptions. The effects of interruptions on subsequent sleep staging vary based on the type of interruption and when the disruption occurs relative to stage R sleep, though in general, disruptions make it harder to fall asleep and, if subsequent sleep occurs, delays deeper sleep [32]. For instance, one study [32] periodically disrupted sleep across the night. Disruptions during N3 sleep resulted in subsequent sleep being lighter between ~48% and ~65% of the time. Another study determined an N3 sleep latency of 28 min under sleep deprivation situations [33]. These studies suggest that disruptions to N3 could lighten subsequent sleep. In addition, sleep after disruptions that occur during or near stage R sleep tend to resume stage R sleep and/or reduce stage R latency [32, 34]. Thus, it is possible that repeated alarms could serially disrupt deeper sleep in favor of ever lighter stages of sleep, and disruptions that occur during or near stage R could increase the likelihood of subsequent stage R sleep. Both effects of sleep disruption could promote the final waking occurring from light sleep regardless of the stage of sleep during the initial sleep disruption. This idea is at least partially supported by a study which found increased snoozing and alarm usage was associated with more frequent lucid dreaming [1], which tends to occur most often during stage R sleep [35].

Snoozing summary

A well-rested, natural wakeup with low sleep inertia is a combined effect of waking to lighter sleep stages and a CAR. When sleep is curtailed, there is a higher chance that a person is waking up from a deeper stage of sleep and is not supported by a CAR. These factors independently and in combination can increase sleep inertia and reduce cognitive performance, increase arousal thresholds, and result in poorer mood. Snoozing could serve as a compensatory behavior that reduces the negative effects of sleep inertia upon waking through increased stress system activation and lightening of sleep stage prior to waking.

Snoozing hypotheses

Little empirical work has examined snoozing impacts on sleep. Our work had two primary aims: (1) to define and measure snoozing behavior, and to provide an initial examination of who, when, how, and why snoozing occurs; and (2) to examine the physiological effects of snoozing on human sleep and HR, both over a long time scale (trait-like), and on the days that it occurs (state-dependent). A questionnaire was generated to measure how and why snoozing is accomplished, and we compared self-identified snoozers along other trait measurements to determine who snoozes. Daily surveys were administered to examine when and how often snoozing occurs. We anticipated snoozing would occur in a sleep restriction context, and sleep restriction is associated with numerous trait-like and demographic effects [7–13]. This led to the hypothesis that self-identified snoozers will be associated with demographic and trait-like constructs previously associated with reduced sleep (e.g. sex, age, and chronotype). The main vehicle of snoozing, alarms, are designed to provide arousal and can generate a stress response. In addition, the action of setting an alarm may serve as a self-awakening trigger, which can increase HR and lighten sleep up to 60 min prior to waking. Finally, multiple alarms could lighten sleep or maintain lighter sleep prior to waking. This led to two hypotheses related to sleep physiology: that snoozers will have increased HR activity and lighter sleep during the last hour of sleep. Each of these hypotheses were examined as a trait that has global effects and as a state, in which snoozing could cause effects at the time snoozing occurred. These effects are not mutually exclusive and can occur independently and in combination, similar to how an individual can have trait-like tendency towards anxiety, and be particularly anxious or relaxed in a particular moment [36]. For instance, habitual snoozers would be expected to have higher HR and lighter sleep regardless of whether or not they snoozed on a particular day (trait-like), and would have higher HR and lighter sleep for snooze days compared to nonsnooze days.

Methods

Participants

This study was approved by the University of Notre Dame Internal Review Board (IRB), study number 17-05-3870. Seven hundred fifty-seven participants enrolled in a larger, year-long study of health and workplace performance to determine if multimodal sensing (wearable, smart phone, social media, and bluetooth beacons) could detect job performance (task performance, organizational citizenship, and counterproductive workplace behaviors), psychological constructs, (e.g. cognitive ability, personality, anxiety, stress, and affect), and health (alcohol use, tobacco use, physical activity, and sleep) [37]. Participants were full-time working professionals with cognitively demanding jobs (e.g. information workers) working in the United States, over 18 years old, salaried, have normal or corrected to normal vision, English language proficiency, and with no known allergies to common wearable components (e.g. nickel in the metal clasps). Participants were administered the Pittsburg Sleep Quality Index (PSQI) [38], but were not screened for sleep disorders or medical conditions. Participants were employees from a mixture of four organizations and universities and surrounding areas [39]. Participants were recruited via email solicitations and by word of mouth from participants for a year-long study of work place performance and multimodal sensing. There was no mention of snoozing, alarm use, or wake up habits in the recruitment materials.

Participants were required to maintain 80% or better compliance across surveys, wearables, and phone app. Noncompliant participants were contacted several times for support and/or troubleshooting. Participants who did not respond or improve compliance were withdrawn as noncompliant. Across the study, 108 participants were withdrawn and their data are not considered in this paper; 74 were noncompliant, while 34 requested to be withdrawn. Of the 34 who requested to be removed, 5 provided no reason, 10 had technical issues, 10 had life changes, and 9 were unwilling to complete surveys or wear the Garmin vivoSmart 3. Of the remaining participants, 460 people completed the Mattingly Alarm and Snooze Survey (MASS, see Supplementary Appendix A). Data from 8 participants were removed due to data entry error, and data from 2 participants were removed due to a lack of wearable data past June 15, 2018 (see Wearables), leaving 450 participants with wearable data and completed trait surveys. Data from these 450 participants were used for descriptive statistics and to test the snoozers have restricted sleep hypothesis and the trait and state HR and lighter sleep hypotheses using 103 169 nights of wearable data. To test state-dependent HR effect and state-dependent lighter sleep hypotheses, a subset of 385 participants were selected who had completed at least 1 day of 7 daily surveys and who also had HR and sleep data from the wearables on the same day, for a total of 1994 daily observations. See Table 1 for the demographics of the 450 participants.

Surveys

A survey during enrollment collected demographic information. Additional constructs were assessed including personality using big five inventory-2 (BFI) [40], which measures personality along the dimensions of conscientiousness, neuroticism, openness, agreeableness, and extraversion. Chronotype was assessed via the morningness-eveningness questionnaire (MEQ) [41]). Mood was assessed with the positive and negative affect schedule (PANAS) [42], anxiety from the state trait anxiety inventory (STAI) [36], and sleep quality from the PSQI [38]. In the last month of a larger study [37], brief daily surveys asking about snoozing and alarm behavior were administered (Supplementary Appendix B) for 7 days at 4 pm via text message. At the conclusion of the survey, the PSQI and a novel survey, the mattingly alarm and snoozing survey (MASS; Appendix A) was administered. The MASS is a novel tool designed to (1) detect snoozing behaviors, (2) determine how alarms and snoozing behaviors are accomplished, (3) identify contributing behaviors, and (4) assess attitudes toward snoozing. This instrument has not yet been validated and the current study will be used to refine the measure for future studies. A Cronbach's α score (21 items, $\alpha = .75$) was calculated, with items 6 and 24 excluded

Table 1. Demographic table

	Overall		Snoozer		Non-snoozer	
Construct	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Body mass index	23.85	6.437	23.8	6.4	23.9	6.48
Age	6.27	10.36	35.2	10	37.7	10.7
Chronotype (MEQ)	47.16	4.94	47.9	5.07	46.1	4.58
Neuroticism (BFI)	2.44	0.79	2.5	0.794	2.37	0.784
Conscientiousness (BFI)	3.92	0.64	3.8	0.664	4.07	0.583
Extraversion (BFI)	3.39	0.68	3.36	0.71	3.43	0.634
Agreeableness (BFI)	3.92	0.56	3.92	0.546	3.92	0.59
Openness (BFI)	3.82	0.63	3.85	0.603	3.78	0.654
Positive affect (PANAS)	34.41	5.97	3.8	5.7	35.2	6.22
Negative affect (PANAS)	17.16	5.14	17.4	5.21	16.9	5.04
Anxiety (STAI)	38.012	9.67	38.8	9.67	36.9	9.57
Sleep quality (PSQI)	5.52	2.92	5.87	3.12	5.06	2.56
Average daily steps	7748.6	4463.57	7249	4291	8390	4598
Average bedtime	11:08 pm	1.66 h	11:21 pm	1.68 h	10:52 pm	1.6 h
Average waketime	07:19 am	1.63 h	07:30 am	1.64 h	07:04 am	1.57 h
Average sleep duration (h)	8.18	1.63	8.15	1.68	8.21	1.57
Average heart rate	65.77	9.85	66.9	8.39	65.0	7.96
	Overall		Snoozer		Non-snoozer	
	Male	Female	Male	Female	Male	Female
Sex	253	197	133	127	120	73

Mean and standard deviation (*SD*) are reported overall for 450 participants, and then the same constructs are reported within snoozer and nonsnoozer. Constructs that are based on validated measures have the survey abbreviation the construct comes from. MEQ = morningness eveningness questionnaire [41], BFI = big five inventory [40], PANAS = positive affect negative affect schedule [42], STAI = state trait anxiety inventory [36], PSQI = pittsburg sleep quality index [38].

as they are of the "other, please describe" type, and item 23 excluded, which allows individuals to endorse all that applies. This indicates acceptable reliability for initial scale development [43].

Wearable

Participants were asked to wear a Garmin vivoSmart 3 to collect steps, HR, and sleep 24 h a day, 7 days a week with the exclusion of showering and charging. This study's average participant wore the device ~74% of the time for the duration of the year-long study, and the median percent of time worn was ~98% [39]. Wearables using photoplethysmography (PPG) to measure HR have been shown to be similar to electrocardiogram (ECG), especially during sleep, though with reduced accuracy during exercise (e.g. beats per minute >165) [44, 45]. This pattern is true for the Garmin vivoSmart 3, which is comparable to other commercial and research grade HR sensors, and has been shown to not meaningfully differ from ECG at rest (though a significant difference of ~10% during physical activity was noted) [46]. HR was monitored continuously and aggregated in 5-min windows that slide by 1-min increments. Wearables are capable of detecting changes in HR related to changes in sleep behavior, such as variability in bed/wake times [47]. In addition to HR, wearables also measure sleep, and have been shown to be accurate in sleep duration detection for adults (e.g. within 9 min of polysomnography [PSG]) [48], especially for adults without sleep or mood disorders such as insomnia or major depressive disorder [49, 50]. For a meta-analysis of commercially available wearable accuracy, see [51]. A validation study of the Garmin vivoSmart 3 compared to PSG found that epoch by epoch accuracy for determining sleep vs. wake was 88% [52]. Wearables also calculate sleep staging, and wearables that use PPG (HR, heart rate variability—HRV) in combination with accelerometer motion detection (as the Garmin vivoSmart 3 does) can outperform sleep staging detected from actigraphy (e.g. [53]). Accuracy of current generation commercially-available wearables compared to PSG ranges from 0.69 to 0.81 for detecting light sleep (N1 + N2), between 0.36 and 0.89 for deep sleep (N3), and between 0.62 and 0.89 for stage R sleep [51, 54]. The Garmin vivoSmart 3 demonstrated an overall accuracy of 69.7% for all sleep staging, similar to Fitbit [55].

From the Garmin vivoSmart 3, two sets of sleep staging scores per day were generated: percentage of time awake, light sleep (N1 + N2), deep sleep (N3), and stage R for the entire night, and the same for the last hour. The last hour (60 min prior to wearable detected wake time) was chosen due to findings of differential sleep staging and physiology for restricted sleepers practicing self-awakening [27]. In addition, HR was calculated across the entire night and last hour. To get a sense of data granularity, the number of measurements per 5-min window was divided by the number of windows captured during the sleep period by participant per day, which yielded an average of 20 (*SD* = 2.54) measurements per window, which translates roughly to a new measurement every 15 s. This calculation was repeated for the last hour with similar results (average 19.8, *SD* = 2.87 measurements per window). The stage R sensing capability was added June 14, 2018 (https://web.archive.org/web/20180625114945/https://www.garmin.com/en-US/blog/fitness/advancedrem/), so wearable data was excluded from before June 15, 2018 to ensure sleep staging percentages for each night were calculated with the same number of categories (stage R, light, deep, and awake).

Analyses

First, the MASS was examined in the areas of alarms and snoozing behaviors, contributing behaviors, and attitudes toward snoozing. Participants were asked if they consider themselves snoozers and were divided based on their response. Distributions of responses from snoozers compared to nonsnoozers in these items were tested using chi-square tests with p-values that were Bonferroni-adjusted given that these analyses are exploratory and nonhypothesis driven [56]. Daily snooze values were examined through pairwise comparisons between three groups (natural wake, alarm, and snooze) using linear mixed-effects models, and repeated after combining natural wake and alarm days into non-snoozing days, as appropriate.

Next, the restricted sleep hypothesis was tested using a logistic regression model to determine what factors previously associated with restricted sleep are associated with differentiating between snoozers and non-snoozers (after controlling for all other items in the model). Specifically, snoozer (y/n) was predicted by demographic information (age, sex), psychological traits (personality, chronotype, sleep quality, positive and negative affect), and physiological traits (BMI, average sleep duration, and average step count).

The hypothesis that snoozers have increased HR during sleep as a trait was tested by linear mixed-effects models of the average HR during the whole night of sleep and in the last hour of sleep with the MASS snoozer status as a predictor while controlling for sleep duration using 10 months of wearable data. The state-dependent hypothesis was tested using the 7 daily responses by fitting a linear mixed-effects model which includes a day-level survey response (snoozed that day, did not snooze that day) that was participant mean-centered as a time-varying predictor and the participant mean as a time-invariant predictor. This procedure disaggregated the state-dependent from the trait-like effect [57]. To test the hypothesis as to whether the snoozers have lighter sleep, simultaneous modeling was conducted on the percentage of wake, light, deep, and stage R sleep across the whole night of sleep and in the last hour of sleep with MASS snoozer status as a predictor using wearable detected sleep data across 10 months of wearable data. A generalized structural equation model with a shared random effect for each sleep stage was used. Intercepts for percentages spent in each sleep stage were constrained to add up to 100%. Similarly, the coefficients for snoozing and sleep duration were each constrained to add to zero. This ensured that the predicted percentages spent in each sleep stage for each group added to 100%. To test this hypothesis as a state-dependent effect, the analysis was repeated using the 7 daily responses with the time-varying and time-invariant snoozing predictor to disaggregate the state-dependent and trait-like effects. Diagnostic tests were performed as appropriate for all models such as normality of residuals, heteroscedasticity, and VIF to ensure that assumptions were met. Because there was some evidence of non-normality and heteroscedasticity, we used robust standard errors in all models. All analyses were conducted in Stata 16.1 [58]. The do-file with the commands used to fit these models is available upon reasonable request.

Results

MASS descriptive statistics

Participants identified themselves as snoozers or non-snoozers, using this definition: "Snoozing can be considered as choosing to go back to sleep after an alarm has awakened you intending to wake up later, setting an alarm earlier than when you intend to wake up, or setting multiple alarms with the intent to not wake up on the first alarm". Of 450 participants, 257 (~57%) said that they were snoozers, while 193 (~43%) said they were not snoozers. Distributions of responses to each item of the MASS are reported in Supplementary Appendix C. Significance tests reported in Supplementary Appendix C have been Bonferroni-adjusted for the 20 tests.

Alarms and snoozing behavior

Chi-square tests between snoozers and non-snoozers on MASS items revealed that participants placed alarms within arm's reach (χ^2 (2, 450) = 15.6, p = .008) and used evenly spaced alarms (e.g. 5 min each time, χ^2 (4, 450) = 77.4 p < .001). For the "other; please describe" alarm interval, 48 participants added responses, summarized here: 22 participants used one alarm, 13 stated they do not snooze, 4 described specific situations that they snooze in (e.g. "I set one alarm early enough to do all of my morning activities with extra time for optional activities. Depending on how tired I am, I'll set a timer after my first alarm to wake me up later."), and 8 provided specific snooze intervals ranging from 9 min to 30 min. Snoozers did not significantly differ in terms of how alarms were set based on the next day's schedule or as part of a regular schedule, (χ^2 (3, 450) = 4.1, p = 1, χ^2 (3, 450) = 12.9, p = .01, respectively). As expected, snoozers used a snooze function on a work day significantly more than non-snoozers (χ^2 (3, 450) = 189, p < .001), and also more often set an alarm after waking (χ^2 (3, 450) = 43.4, p < .001). Snoozers significantly more often slept through an alarm (χ^2 (3, 450) = 23.8, p < .001).

Contributing factors

The MASS asked about possible insufficient sleep contributors to snoozing and behaviors that counteract insufficient sleep (e.g. napping). Napping was uncommon, with 77% of participants napping monthly or not at all, despite 51% of participants feeling at least slightly sleep deprived and 60% at least slightly disagreeing that they got enough sleep. Snoozers did not significantly differ from non-snoozers on nap frequency, (χ^2 (3, 450) = 5.1, p = 1), feelings of sleep deprivation, (χ^2 (4, 450) = 8.3, p = 1), or feelings of inadequate sleep (χ^2 (4, 450) = 9.6, p = .97). However, snoozers felt the environment influenced their snoozing more often than non-snoozers (χ^2 (3, 450) = 17.5, p = .01), fell asleep more easily after waking to an alarm (χ^2 (4, 450) = 86.3, $p \leq .001$), and felt more late or on-time (as opposed to on-time or early) to work compared to non-snoozers (χ^2 (4, 450) = 25.7, p < .001).

Attitudes toward snoozing

Snoozers considered snoozing significantly more important for the workday schedule compared to non-snoozers (χ^2 (4, 450) = 170, p < .001). When asking about attitudes, snoozers and non-snoozers were asked different questions. Snoozers were asked how snoozing makes them feel, while non-snoozers were asked to imagine how snoozing would make them feel if they engaged in snoozing behaviors. Snoozers and non-snoozers significantly differed in distributions of positive feelings regarding snoozing, including improvement of mood (χ^2 (6, 450) = 4.1, p = 1), feelings of happiness (χ^2 (6, 450) = 37.1, p < .001), and feelings of alertness. (χ^2 (6, 450) = 23.9, p = .01). In general, snoozers tended to agree with positive aspects of snoozing, while non-snoozers disagreed with these aspects (see Supplementary Appendix C). For negative views of snoozing, snoozers did not differ from non-snoozers on feelings of guilt (χ^2 (6, 450) = 18.1, p = .12), though they differed in feelings that snoozing worsens mood (χ^2 (6, 450) = 20.5, p = .04) and that snoozing makes one feel nervous (χ^2 (6, 450) = 21, p = .04). In general, snoozers tended to disagree with negative aspects more than non-snoozers (See Supplementary Appendix C). Participants also checked all reasons for snoozing that applied, as well as fill in “other, please describ Supplementary e” (See Table 2). The most endorsed items were: “I don’t snooze”; “I snooze because I cannot get out of bed on my first alarm”; and “I snooze because it is comfortable in my bed”. In addition, 12 participants filled in “other” reasons: 1 is still tired; 1 couldn’t fall back asleep; 2 snoozed because a bed partner did, 2 snoozed to enjoy cuddling; 1 didn’t want to face the day; 1 felt a lack of control due to sleepiness; 3 used snoozing to prepare for the day (e.g. reviewing mental “to-do” lists, listening to the news, etc.); and 1 snoozed to help moisten eyes.

Daily snooze survey descriptive statistics

Daily surveys (Supplementary Appendix B) were administered at 4 pm that asked participants how they woke up today (snooze, alarm only, or no alarm), how much caffeine was consumed, and questions about their morning routine. Any caffeine servings over 8 were reduced to 8 to correct for the mistake of responding in ounces instead of servings (e.g. 64), which adjusted ~3% of values. For those who woke to a single alarm or who snoozed, additional questions were asked about devices used as an alarm (see Table 3), along with questions about the time from the first alarm to getting out of bed. Of 1994 daily responses from 385 participants with corresponding wearable data, method of waking was snoozing 620 (~31%) days, by a single alarm 600 (~30%) days, and no alarm 774 (~39%) days. Examining the 774 days that were not woken to an alarm, 484 (~63%) were woken naturally without any other factors, 237 (~31%) were woken by external factors such as a pet, children, construction noise, light, etc., while 53 (~7%) were woken by personal factors such as injury, medical condition, stress, anxiety, excitement, etc. Pairwise comparisons were conducted between three groups (natural wake, alarm, and snooze) for daily sleep duration, caffeine consumption, time between first alarm and getting out of bed (for alarm and snoozers only, as natural wake did not use any alarm), and on duration of morning routine. Sleep duration on natural sleep days (8.74 h ± 3.77 min) significantly differed from sleep duration on alarm days (7.83 h ± 3.54 min) and from snooze days (7.95 h ± 3.66 min), though sleep duration on alarm days and snooze days did not significantly differ from each other (z = −9.93, p < .001, z = −8.01, p < .001, and z = 1.12, p = .26, respectively). On natural waking days, participants consumed 1.7 ± 0.06 servings of caffeine, which was not significantly different than 1.9 ± 0.08 servings of caffeine on alarms days and was significantly different compared to 2.06 ± 0.07 servings of caffeine on snooze days, though alarm and snooze days did not significantly differ from each other (z = 1.82, p = .07, z = 3.91, p < .001, and z = 1.12, p = .26, respectively). There were no significant differences in duration between waking and going to work/morning routine between natural wake (1.51 ± 0.17 h), alarm days (1.85 ± 0.27 h), and snooze days (2.12 ± 0.31 h) (z = 1.15, p = .25, z = 1.75, p = .08, and z = .65, p = .52, respectively). Time between first alarm and getting out of bed was significantly longer for snoozers (26.93 ± 0.97 min) than alarm users (8.48 ± .68 min), z = 11.75, p < .001. After combining natural wake days with alarm days to reflect the non-snooze versus snooze comparison of the MASS, non-snooze days had 8.34 ± 0.05 h sleep duration, 1.78 ± 0.05 servings of caffeine, and 1.66 ± 0.15 h of morning routine. Non-snooze days significantly differed from snooze days on sleep duration (z = −5.04, p < .001) and caffeine consumption (z = 3.74, p < .001), but did not significantly differ on morning routine duration (z = 1.35, p = .17). Alarm duration was not compared given that natural waking days (a component of nonsnoozing days) did not have an alarm duration.

Table 2. Additional reasons for snoozing

N	Reasons for snoozing
125	I do not snooze
110	I snooze because I cannot get out of bed on my first alarm
109	I snooze because I feel comfortable in bed
60	I snooze because it allows me to feel less tired when I do get out of bed
45	I snooze because it makes me feel more pleasant in the moment
38	I snooze because it is part of my structured routine
14	I snooze because it allows me to feel more in control
12	I snooze for another reason
12	I snooze because I think it will improve my work performance
10	I snooze because it will make me feel more pleasant later

Participants were allowed to check all that apply. Participants could check more than one response.

Predicting snoozing from relevant demographics, physiology, and psychological constructs

Table 4 provides the odds ratios and corresponding z-tests from a logistic regression using snoozer status as the dependent variable. Multicollinearity was assessed by examining the variance inflation factor (VIF) of the predictors. All GVIF features were <5, and GVIF^(1/(2*Df)) features were all <3, indicating that collinearity was not an issue [59, 60]. A Hosmer-Lemeshow goodness of fit test with 10 groups (χ^2= 6.58, df = 8, p = .583) was not significant, indicating adequate model fit. The area under the curve

Table 3. Device used to assist with wake for non-natural waking, count of days

Device	Count
Cell phone alarm	844
Bedside clock with alarm function	214
Garmin vivoSmart3, other wearable, or vibration alarm	177
Alarm app or Sleep app on cell phone	132
Other, not including naturally waking up	50
Specialized wake device	23

for this model is 0.70. The odds of self-identifying as a snoozer decreased by 2% for each year older and were 50% smaller for men than women. For each additional 1000 average daily steps, the odds of self-identifying as a snoozer decreased by 11%. The odds of being a snoozer were 48% lower for each additional point increase in conscientiousness, and 6.1% higher for each additional point increase on the MEQ (higher MEQ means more evening type).

Trait-like snoozing, HR

The full model results of the mixed-effects models on average whole night HR and the average last hour HR are reported in Supplementary Appendix D. Snoozers had an average HR of 1.86 additional beats per minute for the whole night (z = 2.41, $p = .016$), and 1.62 additional beats per minute in the last hour (z = 2.22, $p = .027$), see Figure 1. There was substantial intraindividual (var = 41.50, 95%CI [38.69, 44.52]) and interindividual (var = 59.32, 95% CI [52.11, 67.52]) variability in HR in the last hour, and over the whole night: var = 30.24, 95% CI [27.91, 32.77] and var = 66.91, 95% CI [58.97, 75.93], respectively.

State-dependent vs. trait-like snoozing, HR

The results of the mixed-effects model including participant mean-centered snoozing and participant means for snoozing that day revealed differences in state- versus trait-like effects of snoozing. Over the whole night of sleep, participants who snoozed (trait-like) had an average HR of 3.35 more beats per minute than non-snoozers (z = 2.11, $p = .035$), while snoozing on a particular day (state-like) decreased HR by 0.83 beats per minute (z = −2.44, $p = .014$.). The pattern for the last hour is similar but each effect fails to reach significance.

Trait-like snoozing, sleep staging

Percentages spent in each sleep stage were simultaneously modeled in a generalized structural equation model (GSEM) using the MASS snoozer status as the predictor of interest and controlling for sleep duration. Wald tests revealed significant main effects of routinely snoozing both on the whole night (χ^2 (3) = 8.6, $p = .035$) and the last hour of sleep staging ($\chi^2(3) = 8.45$, $p = .038$. Across the whole night, no individual stage was significantly different between snoozers and non-snoozers. In the last hour, snoozers spent 2.19% more time in light sleep (z = 2.85, $p = .004$), and 1.86% less time in deep sleep (z = −2.29, $p = .022$).

Trait-like vs. state-dependent snoozing, sleep staging

The same GSEM models were conducted using the day-level and participant-level snoozing predictors on sleep staging to disaggregate trait- from state-dependent effects of snoozing. Wald tests revealed significant main effects of routinely snoozing both on the whole night (χ^2 (3) = 12.75, $p = .0052$) and the last hour of sleep staging (χ^2 (3) = 10.73, $p = .0133$). In addition, snoozing on the day significantly impacted the last hour of sleep (χ^2 (3) = 14.13, $p = .0027$) see Figure 2. Specifically, participants who snoozed more often spent 2.39% less of their total sleep in stage R sleep than non-snoozers across the whole night (z = −3.44, $p < .001$). In the last hour, snoozers spent 4.50% less time in stage R sleep (z = −2.70, $p = .007$) and 6.37% more time in light sleep (z = 2.49, $p = .01$). For days when a participant snoozes, participants spent 4.7% more time in light sleep (z = 2.76, $p = .006$), and 3.83% less time in deep sleep (z = −3.36, $p < .001$) in the last hour.

Discussion

Our results show a majority of sampled participants were habitual snoozers, and snoozing likelihood significantly varied over several demographic and behavioral traits. Naturally waking days had significantly more sleep than single alarm and snooze days, which did not differ from each other in wearable measured sleep duration. The scope of snoozing is expected, due to one in three Americans being chronically sleep-restricted [61], and unexpected, given that sleep scientists and medical doctors consider snoozing as possibly harmful [2–6]. Snoozing was not

Table 4. Odds ratios from logistic regression to predict likelihood of identifying as a snoozer

Snoozer	Odds ratio	Std. err.	z	P > z	[95% confidence interval]	
Age	0.98	0.01	−2.29	**.029***	0.96	1.00
Gender (male)	0.51	0.12	−2.84	**.005****	0.32	0.81
Body mass index	1.00	0.0002	−0.61	.544	1.00	1.01
Avg. steps (1000)	0.89	0.04	−2.66	**.008****	0.81	0.97
Avg. sleep duration	1.00	0.00004	−1.05	.29	1.00	1.00
Extraversion	1.04	0.20	0.23	.82	0.72	1.52
Conscientiousness	0.52	0.10	−3.37	**.001*****	0.35	0.76
Agreeableness	1.12	0.24	0.55	.579	0.74	1.70
Neuroticism	0.94	0.21	−0.29	.775	0.60	1.46
Openness	1.13	0.20	0.72	.470	0.81	1.59
Positive affect	0.98	0.02	−0.86	.389	0.93	1.03
Negative affect	1.00	0.03	0.01	.991	0.94	1.06
Anxiety	0.99	0.02	−0.30	.761	0.95	1.04
Sleep quality	1.08	0.04	1.97	**.049***	1.00	1.18
Chronotype	1.06	0.02	2.67	**.007****	1.02	1.11
_cons	26.33	64.40	1.34	.181	0.22	3177.74

Personality measurements (extraversion, conscientiousness, agreeableness, neuroticism, and openness) from the BFI [40], Positive affect and negative affect from the PANAS [42], Anxiety from the STAI trait [36]. Sleep quality from the PSQI [38]. Chronotype from the MEQ) [41].

$^{*}P < .05$, $^{**}P < .01$, $^{***}P < .001$.

Bold indicates significant values.

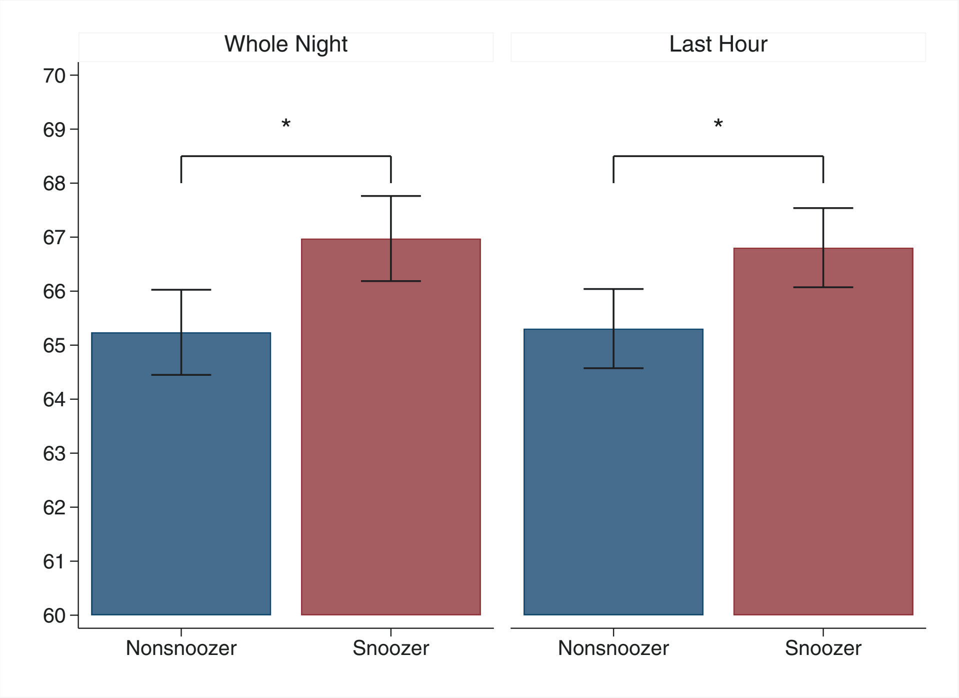

Figure 1. Heart rate across 10 months for snoozers vs. non-snoozers. Heart rate during the entire sleep period (right), and from the hour before wearable detected waking (right).

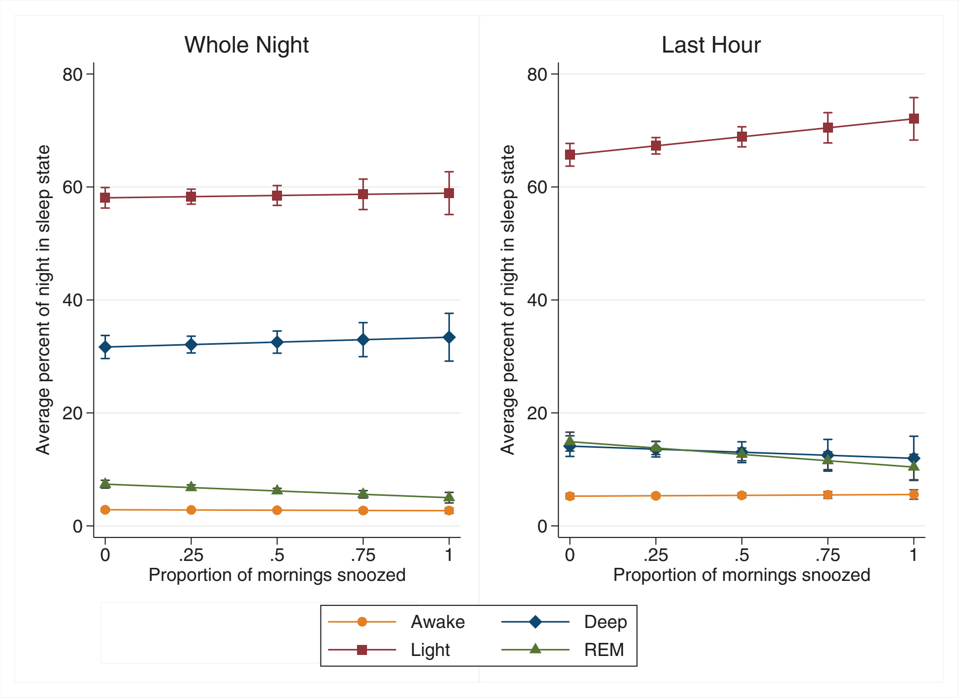

Figure 2. Sleep staging concentrations across 7 days. Sleep staging during the whole night (left), and during the last hour (right). Proportion of mornings snoozed out of days responded. Sleep staging adds up to 100%.

associated with subjective measures of sleepiness, but was associated with poorer PSQI scores. While these findings could be interpreted as evidence against the snoozers have restricted sleep hypothesis, it is more likely due to measurement error in both wearables and sleep surveys. Wearables are unlikely to sense snoozing, given that wake time is generated from movement rather than cognitive alertness. This possibility allows wearables to generate the observed similar wake times for snoozers and non-snoozers, even if snoozers are cognitively alert prior to getting out of bed. Indeed, a recent study of the Tesserae data reports that wearables overestimate sleep compared to self-report by ~46 min, but that discrepancy can be reduced to 8 min if wearable data is corrected by cell phone usage [62], which could reflect cognitive alertness in the absence of movement. This reflects our survey findings, with ~75% of alarm and snoozing originated from a cell phone, and the average time spent snoozing before getting out of bed was 26.93 min. Snoozing could also reduce measurement accuracy within established sleep surveys, such as the PSQI [38], which do not offer participants instructions for how to treat snoozing. For instance, PSQI question 4 asks "During the past month, how many hours of actual sleep did you get at night? (This may be different than the number of hours you spend in bed.)" [38]. A habitual snoozer could consider time awake as the first alarm, in which case time in bed would be 26.93 min longer, or they could consider that time as sleep. This variability could increase measurement error in PSQI scores. PSG studies of snoozing will be critical in determining if snoozers objectively have less sleep, how much correction wearables could require, and for determining how snoozing is incorporated into self-report measurements such as the PSQI. For instance, if a participant is awake after the first alarm, then a participant could begin overcoming sleep inertia, which takes at least 21 min to dissipate [16].

Snoozers had trait-like increased wearable measured HR over the whole night and in the last hour in both 10 months and 1 week of data. As a state-dependent effect, there was a significant (though modest) reduction in resting HR for the whole night. This reduction in state-like HR when snoozing could be due to other factors such as the routineness of snoozing, similar to how habitual nappers derive the largest benefits from naps (for review, see [63]). For a habitual snoozer, a disruption to routine (not snoozing) could be a stressful interruption. For a non-snoozer, choosing to snooze could reflect either an uncommonly relaxed anticipated day, or it could be used as a way to insulate against an anticipated exceptionally stressful day (e.g. setting multiple alarms to avoid missing an important meeting). Both examples could explain the observed state-like reduction in HR, and future studies that examine stress and snoozing will need to differentiate these possibilities, for instance by asking about snoozing motivation. Different motivations for snoozing and causes of lower resting HR for snoozers and non-snoozers could explain why snoozers show trait-like increased resting HR and all participants show a lower HR on days they snoozed.

Snoozers had trait-like lighter sleep as measured by wearables across the whole night and in the last hour of sleep. In the last hour, snoozers has significantly more light sleep and less deep sleep. Evidence for a state-like effect was limited, and only evident in the last hour before waking. However, wearable sleep stage findings will require PSG validation (see limitations). If our wearable sleep staging results are validated, it would suggest that snoozing could share common mechanisms with "self-awakening" (intending to wake at a particular time before going to bed). Self-awakening has been shown to change arousal hormones and increase HR 1 h prior to the intended waking time [27], and to reduce sleep inertia upon waking. Thus, it may be that the anticipation of alarm(s) may change sleep staging in anticipation of waking. However, unlike results reported in [27], we see increased HR across the entire night for snoozers.

Wearables detected limited evidence of increased arousal and lighter sleep the hour before waking and increased resting HR across the entire night, both in general for snoozers and specifically on days that individuals snooze. This is in line with previous literature, which suggests that anticipating a sleep disruption via an alarm (being "on-call") can increase physiological stress and lighten sleep [64–68], whether or not sleep was actually disturbed by an alarm. It is possible that this increased physiological activity is associated with single alarms and snoozing. Indeed, alarm and snooze days did not differ from each other on time asleep or caffeine consumption, only in time spent in bed after the first alarm. Whether from snoozing or any alarm usage, it is likely that this increased arousal is a double-edged sword. In the short term, the lighter sleep and increased HR may increase the success of alarms for waking a participant, may reduce sleep inertia [28, 29, 69], or improve mood. In the long term, chronically reduced sleep and chronically increased resting HR are associated with numerous negative health outcomes including diabetes, heart disease, and mortality (e.g. [70, 71]).

Limitations

Wearables are relatively recent and have become increasingly common as research tools that allow for large scale, in-situ, objective physiological, and behavioral data collection (e.g. [37, 72]). However, their agreement with more validated measures such as PSG sleep staging is more variable and circumstance dependent, if independent validation exists [73–76]. For instance, reliability is likely worse in situ, (e.g. [77]), in nonstandard populations [78], and during sleep stage transitions [79], which snoozing might increase. Given that it is unlikely that wearables are sensitive to awakenings as induced by snoozing and the variable reliability of wearable detected sleep staging, Our sleep stage findings will require validation using PSG.

Our wearables used PPG sensors to detect HR. While HR detection is also variable relative to more validated measures such as electrocardiogram (EKG) [45, 80–82], PPG sensors tend to perform their best when individuals are stationary, as when asleep. PPG HR measurement is prone to periods of missing data, which can impair their ability to generate accurate measures [83, 84]. An additional limitation is that PPG HR measurement reliability has not been evaluated during a period of snoozing, or in the presence of multiple alarms. Our use of HR cannot measure the dynamic interactions of the SNS and parasympathetic nervous system which both influence HR, and it is possible that the observed changes in HR from snoozing arise from a reduction in parasympathetic activity rather than an increase in SNS activity [85]. While more nuanced HR analysis methods, such as HRV spectral analysis, can begin to differentiate the effect of SNS and parasympathetic activity in HR measurements [86], we could not confidently assess HRV in our timeframe. These drawbacks make it impossible to assess subtle effects of snoozing on HR in the minutes preceding wake above and beyond the whole night increase resting HR. It will be critical for future snoozing studies to utilize gold standard measurements such as PSG and EKG to examine differences in sleep architecture and HR.

In addition to limitations of wearables, we were also limited by our study design. We did not collect cortisol and so cannot comment on snoozing effects on the HPA axis or the CAR, nor did we assess sleep inertia upon waking. However, traditional salivary measures of the CAR may interfere with snoozing, so CAR measurement during snoozing may require blood sampling of cortisol [87] which would allow participants to remain asleep or engage in snoozing before waking without disruption. In addition, we asked about no alarm waking in daily surveys, but not as a trait. We cannot comment on how many of the non-snoozers are habitual alarm (but not snooze) users vs how many habitually wake naturally. Another limitation is the substantially smaller number of daily surveys administered to examine no alarm waking, alarm usage, and snoozing. This may have contributed to different local patterns unique to the 7-day span the items were asked. While the majority of no alarm days were natural waking (~62%), a sizeable percentage were still interrupted sleep (~28% due to external causes and ~6% due to personal factors). While not setting an alarm may benefit sleep physiology before waking, unanticipated waking to other factors such as children or pets could show different effects upon waking and upon sleep inertia (e.g. via the presence of lack of a CAR). Future studies should consider seasonal effects, test-retest validity, and additional power to differentiate between no alarms, natural wake, single alarms, and snooze physiology.

Finally, our sample was relatively homogenous and restricted to full-time salaried professional information workers that were primarily college-educated and with higher income. It is possible that this group has less sleep restriction than is typical, which may limit the generalizability of our findings. If this is the case, it may be possible that stronger relationships between snoozing and sleep duration may be found in a more representative sample or in one with additional variability in sleep duration. Our sample cannot determine what the likelihood of snoozing would be in different age groups, which may have significantly different work schedules (e.g. shift work) or school schedules. In addition, it is unclear how snoozing interacts with education or SES; on one hand, those with higher SES may have more opportunity to snooze, while on the other, those with lower SES sleep less on average [88–91], and thus may have more "need" for snoozing as a coping mechanism to compensate for chronic sleep restriction. Participants were not screened for sleep disorders or for medications that would influence sleep architecture. It is possible that snoozing behavior would be more common in those with other sleep pathologies, such as insomnia.

Future directions

Given the prevalence of snoozing behavior (>50% in our sample), more research is needed to understand snoozing. Most importantly, a deeper understanding of the underlying physiology of snoozing (HR, sleep staging, stress hormones, and sleep inertia) will be required, which in turn can determine how snoozing behaviors should be integrated into naturalistic research and naturalistic sleep measurement. For instance, is the time a snoozer spends in bed snoozing considered sleep, or wake? Generating a consensus on how to treat snooze time could also reduce measurement error in wearables and surveys. Snoozing should also be examined in the context of tradeoffs. If an initial arousal from the first alarm during snoozing begins to dissipate sleep inertia, then the observed average 26.93 time in bed duration of snoozing could ensure no cognitively demanding tasks occur until sleep inertia is overcome, which can occur in as little as 21 min [16]. Reduced sleep inertia before a commute to work could improve safety [92]), but it may come at significant long-term health drawbacks. For instance, snoozers have habitually higher resting HR, which is associated with heart disease (e.g. [70]). Snoozing also needs examination in the context of sleep debt [93, 94], which also alters sleep architecture. Future studies could also examine the utility of snoozing as an intervention to combat sleep inertia and could be assessed and compared to other common sleep inertia countermeasures such as exercise [95] or caffeine consumption. For instance, caffeine cessation could result in withdrawal symptoms [96], whereas snoozing effects may not persist past the day snoozing occurs. Future research should aim to determine the importance of differences (or lack thereof) between snoozing specifically and alarm usage. It may be that any kind of alarm usage, from any modality (phone, alarm clock, and wearable vibration) is hazardous to health. If snoozing is determined to primarily be hazardous to health, a better understanding of snoozing could enable recommendations against snoozing to be more specific [2–6], and could also be used in developing strategies to discourage, reduce, or counteract snoozing.

In addition to understanding the physiology of snoozing, future work should consider how to measure the prevalent behavior of snoozing in-situ. Smartphone and wearable combinations offer a promising avenue to measure snoozing naturalistically, and incorporating these streams together could detect snoozing and reduce discrepancies between self-report, phone usage, and wearables as in [62]. Widespread measurement would also allow for an assessment of snoozing's broader impact on society. For instance, snoozing could be more prevalent in school-aged children, or in those with disadvantageous sleep situations, including those who are chronically sleep deprived or stressed, those who engage in shift work, those with sleep disorders, those with lower socioeconomic status, or those with reduced access to physical and/or mental health care. In addition, important questions remain about what factors drive a person to snooze on a day-to-day basis. For instance, it is possible that individuals only snooze on work days, but would not snooze on days off or on holidays, or that daily stress influences decisions about whether to snooze or not, and snoozing may influence subsequent stress. Future versions of the MASS should include questions to specifically compare snoozing behaviors in these situations and associate them with other relevant surveys. In addition, the MASS should undergo further validation and refinement. As an example, latent profile analysis could determine if there are different subtypes of snoozers, for instance, those who snooze as part of a regular routine, those who snooze in reaction to extreme sleep inertia, and those who snooze opportunistically.

Conclusion

In conclusion, snoozing is a common behavior. We present preliminary evidence that snoozing is associated with lighter sleep in the last hour before wake and higher resting HR across the night, both in general and specifically on nights when one snoozes. Snoozing is not associated with decreased sleep duration, increased sleepiness, or increased naps. Being female, younger, accomplishing fewer daily steps, having lower conscientiousness, having more disturbed sleep, and a more evening chronotype increased the likelihood of being a snoozer. More gold-standard research is needed to understand the physiology of snoozing and how snoozing should be addressed in sleep science.

Supplementary material

Supplementary material is available at *SLEEP* online.

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