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The dynamics of affect across the wake-sleep cycle: From waking mind-wandering to night-time dreaming☆

Pilleriin Sikka[a,b,c,*], Katja Valli[a,b,c], Antti Revonsuo[a,b,c], Jarno Tuominen[a,b]

[a] Department of Psychology and Speech-Language Pathology, University of Turku, Finland
[b] Turku Brain and Mind Center, University of Turku, Finland
[c] Department of Cognitive Neuroscience and Philosophy, University of Skövde, Sweden

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ABSTRACT

Affective experiences occur across the wake-sleep cycle—from active wakefulness to resting wakefulness (i.e., mind-wandering) to sleep (i.e., dreaming). Yet, we know little about the dynamics of affect across these states. We compared the affective ratings of waking, mind-wandering, and dream episodes. Results showed that mind-wandering was more positively valenced than dreaming, and that both mind-wandering and dreaming were more negatively valenced than active wakefulness. We also compared participants' self-ratings of affect with external ratings of affect (i.e., analysis of affect in verbal reports). With self-ratings all episodes were predominated by positive affect. However, the affective valence of reports changed from positively valenced waking reports to affectively balanced mind-wandering reports to negatively valenced dream reports. These findings show that (1) the positivity bias characteristic to waking experiences decreases across the wake-sleep continuum, and (2) conclusions regarding affective experiences depend on whether self-ratings or verbal reports describing these experiences are analysed.

1. Introduction

We spend a large proportion of our lives in states of consciousness where we outwardly seem to be doing nothing, yet inwardly experience rich mental content. Such resting state subjective experiences, involving a stream of thoughts, feelings, and imagery, are largely independent of the external environment and occur across the wake-sleep cycle—from daytime mind-wandering (or day-dreaming) to night-time dreaming (Fox, Nijeboer, Solomonova, Domhoff, & Christoff, 2013; Windt, 2021). These internally generated subjective experiences arguably reflect the processing of past memories and the simulation of possible future events (Fox et al., 2013; Revonsuo, Tuominen, & Valli, 2016; Wamsley, 2013). The content of these experiences—especially the affective content—is tightly linked to our well-being. For example, negatively biased spontaneous cognition in wakefulness (e.g., rumination and worry) as well as the negative content of dreams (e.g., nightmares) are associated with various mental health disorders, such as depression and anxiety

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* Corresponding author at: Department of Psychology and Speech-Language Pathology, University of Turku, Assistentinkatu 7, FIN-20014 Turku, Finland. Department of Cognitive Neuroscience and Philosophy, University of Skövde, Sweden.
E-mail addresses: pilsik@utu.fi, pilleriin.sikka@his.se (P. Sikka).

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(DuPre & Spreng, 2018; Levin & Nielsen, 2007; Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). However, we know little about the dynamics of the affective content of subjective experiences across these states of consciousness.

1.1. Continuity between waking mind-wandering and night-time dreaming

Typically, the conscious subjective experiences we have during wakefulness and sleep are considered distinct because they occur in different behavioural and neurophysiological states. But it is increasingly recognized that subjective experiences occurring across the wake-sleep cycle lie on a continuum and rely on shared brain mechanisms (Christoff, Irving, Fox, Spreng, & Andrews-Hanna, 2016; Domhoff & Fox, 2015; Domhoff, 2011a; Fox et al., 2013; Siclari et al., 2017; Wamsley, 2013; Windt, 2010, 2021). According to the dynamic framework of spontaneous thought, mind-wandering is a state in-between waking goal-directed thought and dreaming: it is more constrained by cognitive control mechanisms than dreaming but less constrained than goal-directed thought (Christoff et al., 2016). Waking goal-directed thought occurs in so-called active wakefulness and is related to external stimuli or immediate task at hand. In contrast, both mind-wandering and dreaming are internally generated subjective experiences that are largely stimulus-independent (Fox et al., 2018; Windt, 2021). The difference is that, whereas mind-wandering occurs during wakefulness, dreaming occurs during sleep. Another difference is that, whereas dream experiences are spontaneous, mind-wandering can be spontaneous or more intentionally directed (Fox et al., 2018). Dreaming is also more immersive than mind-wandering: dreams are taken as reality while experienced, whereas during mind-wandering we generally maintain at least some level of awareness of the present surroundings (Fox et al., 2013). A notable exception is lucid dreaming during which people are aware that they are dreaming.

Nevertheless, the phenomenology of subjective experiences is considered continuous across wakefulness and sleep (Christoff et al., 2016; Foulkes & Fleisher, 1975; Fox et al., 2013; Perogamvros et al., 2017; Wamsley, 2013). In fact, according to the so-called simulation theories of dreaming, dreaming is a mental simulation of the waking world (Domhoff, 2018; Foulkes, 1985; Nielsen, 2010; Revonsuo et al., 2016; Snyder, 1970; Tart, 1987). However, theories differ regarding the type and degree of continuity between waking and dream experiences. Whereas the incorporation continuity hypothesis proposes that dreams directly reflect waking events and experiences (Domhoff, 2017; Schredl & Hofmann, 2003; Schredl, 2003)[1], other theories consider dreaming to be a more selective simulation of waking life. For example, the neurocognitive theory of dreaming argues that dreams reflect only those waking experiences that are of significant personal concern to us and likens dreaming to an intensified form of mind-wandering (Domhoff, 2011a, 2018; see also Domhoff & Fox, 2015; Fox et al., 2013). The threat simulation theory (Revonsuo, 2000) posits that dreaming specifically simulates threatening events (e.g., being chased or attacked). It argues that this function was selected for in our evolutionary past since it helped practice threat perception, recognition, and avoidance responses for wakefulness and, as such, was beneficial to our survival and reproduction (Revonsuo, 2000; Valli & Revonsuo, 2009). Regardless, all these theories agree that our subjective experiences in wakefulness, especially during resting wakefulness or mind-wandering, and dreaming are not categorically different.

1.2. Affect experienced during mind-wandering and dreaming

Affect—here referred to as the subjective experience of emotions and mood (i.e., feelings)—is central to both mind-wandering and dreaming (Fox et al., 2013, 2018). Several studies have investigated affective experiences either during mind-wandering or dreaming. These studies show that in healthy non-clinical populations mind-wandering is, on average, mildly positively biased, that is, characterized by more positive than negative affect (for a review, see Fox et al., 2018). Dreams are often found to be negatively valenced (e.g., Hall & Van de Castle, 1966; Merritt, Stickgold, Pace-Schott, Williams, & Hobson, 1994; Nielsen, Deslauriers, & Baylor, 1991), although they can also have a balanced affective tone (e.g., Blagrove, Farmer, & Williams, 2004; Fosse, Stickgold, & Hobson, 2001; Strauch & Meier, 1996; Yu, 2007) or be predominated by positive affect (e.g., Sikka, Valli, Virta, & Revonsuo, 2014; Sikka, Feilhauer, Valli, & Revonsuo, 2017). However, only a few studies have directly compared affect across these two states of consciousness in the same participants.

Carr and Nielsen (2015) compared the content of mind-wandering—what they called daydreams—with daytime rapid eye movement (REM) and non-rapid eye movement (NREM) nap dreams in the sleep laboratory. Daydream reports and participants' self-ratings of affect experienced during daydreaming were obtained during a 3-minute period of resting wakefulness before the naps. The same method was used to obtain nap dream reports and self-ratings of affect experienced in nap dreams. The authors found that daydreams contained a higher intensity of positive affect than NREM nap dreams but did not differ from REM nap dreams. In a follow-up study, using a similar procedure as in the first study, the authors (Carr, Blanchette-Carrière, Solomonova, Paquette, & Nielsen, 2016) showed that daydreams were more positive than (either REM or NREM) nap dreams, with no difference with respect to negative affect. Because the two studies did not focus on affect per se, the authors did not statistically analyse the relative difference in positive versus negative affect. Descriptive statistics indicated that, whereas in both studies daydreams were rated to contain relatively more positive than negative affect, results regarding dream affect were more variable: in the first study (Carr & Nielsen, 2015) (NREM and REM) nap dreams had relatively more positive than negative affect, whereas in the second study (Carr et al., 2016) nap dreams contained relatively more negative than positive affect.

Perogamvros et al. (2017) content analysed "high-thought" reports (i.e., reports rated to be thought-like) obtained during a 30-minute period of resting wakefulness (upon having been prompted with a sound) and upon awakening from night-time (REM and NREM)

[1] The incorporation continuity hypothesis is distinguished here from the more specific cognitive continuity hypothesis, which argues that dreams reflect waking conceptions and concerns, not waking events and experiences more generally (see Domhoff, 2011b, 2017 for a discussion).

sleep in the sleep laboratory. They found that REM dream (thought) reports contained more positive affect than spontaneous waking (thought) reports, with no differences in negative affect. There were no differences between NREM dream (thought) reports and waking (thought) reports. Although not statistically analysed, waking reports had a rather balanced amount of positive and negative affect, whereas (NREM and REM) dream reports contained relatively more positive than negative affect.

In a recent study, Gross et al. (2021) used an experience-sampling method to compare the content of waking thoughts, or what the authors called stimulus-dependent thoughts, with two types of stimulus-independent thoughts—those occurring during waking mind-wandering and night-time dreaming. Participants were signalled several times during the day and night. Upon receiving the daily signal, participants had to indicate whether the thoughts they were having at the moment of signalling were stimulus-dependent (i.e., externally focused) or stimulus-independent (i.e., internally focused). Responses to nightly signals were considered stimulus-independent thoughts or “dreaming thoughts”. Participants were asked to rate the phenomenological quality of all the thoughts on ten dimensions, including emotionality and emotional valence. Results showed that the emotionality of thoughts that occurred during mind-wandering and dreaming did not significantly differ, although both were more emotional than waking thoughts. Thoughts occurring during mind-wandering were more positively valenced than those occurring during dreaming, but there were no differences in negative valence. Furthermore, while thoughts during mind-wandering were more positive than waking thoughts, thoughts during dreaming were more negative than waking thoughts.

In summary, studies comparing the affective nature of mind-wandering and dreaming are scarce and findings mixed. The latter is likely due to the large variation in methods used for obtaining and analysing data. Importantly, only one study (Gross et al., 2021) has systematically compared the affective quality of waking mind-wandering and night-time dreaming in the same participants outside the laboratory environment. However, in that study the focus was on (stimulus-independent) thoughts in the narrower sense, rather than subjective experiences more broadly.

1.3. Self- and external ratings of affect across wakefulness and sleep

Affective experiences are typically measured using self-ratings (SR) of affect, that is, participants’ own ratings of the affect they experience(d) at a particular time period. Less often, albeit increasingly so, participants’ affective language is analysed either by external judges or by automated linguistic analysis software. Because such affective content analysis of text produced by the participants is not done by participants themselves, we refer to this as external ratings (ER) of affect.

Both SR and ER of affect are assumed to reflect subjective affective experiences. As such, the two measures should yield similar results with regard to affective experiences. However, studies directly comparing SR and ER of affect have demonstrated that these two methods of measurement yield different, even contradictory, results. Specifically, with SR of dream affect (i.e., participants’ ratings of the affect they experienced in the preceding *dream episode*), as compared to ER of dream affect (i.e., ratings of affect expressed in the narrative *dream report*), dreams are rated to contain more affect, especially positive affect (Röver & Schredl, 2017; Schredl & Doll, 1998; Sikka et al., 2014, 2017). As a result, whereas with ER dreams appear to be mostly negatively biased (i.e., more negative than positive affect), with SR the same dreams appear to be mostly positively biased (i.e., more positive than negative affect) or to have a more balanced affective tone (Sikka et al., 2014, 2017). Moreover, SR and ER of negative affect are more strongly correlated than SR and ER of positive affect (Röver & Schredl, 2017; Schredl & Doll, 1998; Sikka et al., 2014, 2017) indicating that the two methods diverge especially in the measurement of positive affect. Importantly, SR and ER of dream affect are also differently associated with waking well-being (Sikka, Pesonen, & Revonsuo, 2018).

Similar discrepancies have been found in the measurement of waking affect (e.g., Bantum & Owen, 2009; Tov, Ng, Lin, & Qiu, 2013). For example, Sun, Schwartz, Son, Kern, and Vazire (2020) reported that there were no significant associations between SR of affect and the analysis of everyday spoken language of the same episodes. However, only one study has directly compared SR and ER of waking and dream affect in the same individuals (Kahan & LaBerge, 1996). It was found that with SR, as compared to ER, both dream and waking episodes were rated to contain more affect. Since the researchers did not investigate positive and negative affect separately, it is not known whether discrepancies in valence obtained in the measurement of dream affect also apply to the ratings of waking affect. Moreover, no studies have compared SR and ER of affect in mind-wandering episodes and reports. Thus, it remains to be determined whether the use of different measures—SR and ER—can explain inconsistencies in findings regarding the dynamics of affect across the wake-sleep cycle.

1.4. Aims and hypotheses of the present study

The first aim of this study was to investigate the similarities and differences between mind-wandering and night-time dreaming in the prevalence and valence of affect. Based on existing studies, we expected mind-wandering to be relatively more positively valenced than dreaming. However, different dream theories yield slightly different predictions. According to the incorporation continuity hypothesis (Schredl & Hofmann, 2003; Schredl, 2003), dream affect should reflect affect experienced during wakefulness and, hence, the proportion of positive to negative affect should be similar during dreaming and mind-wandering. According to the neurocognitive theory (Domhoff & Fox, 2015; Domhoff, 2018), dreams should contain more (intense) positive and negative affect than mind-wandering. According to the threat simulation theory (Revonsuo, 2000; Valli & Revonsuo, 2009), dreams should be negatively biased within (i.e., contain more negative than positive dream affect) and across (i.e., contain more negative affect and less positive affect than mind-wandering) different states of consciousness. The second aim of the study was to compare SR and ER of affect across active wakefulness, mind-wandering, and dreaming. Based on previous studies, we hypothesized that across all three states of consciousness SR, as compared with ER, would yield (1) higher ratings of affect, and (2) especially, higher ratings of positive affect.

2. Method

2.1. Participants

Participants include healthy adults with no sleep disorders, no neurological or psychiatric diagnoses, with good sleep quality, and who reported no use of any medications affecting the central nervous system. We used a convenience sample consisting of university students, staff, and alumni.

Data were collected as part of two different data collection efforts. Regarding data collection I, of the 92 volunteers showing interest in participating in the study, after screening and gender matched sleep quality scores (as measured with the Pittsburgh Sleep Quality Index, PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989), 16 participants were selected. One participant failed to provide any dream reports and was thus omitted from the analyses. The final sample of data collection I includes 15 participants (8 males, 7 females), with ages ranging from 20 to 46 ($M = 25.00$, $SD = 6.25$), who provided 548 waking, 195 mind-wandering, and 170 dream reports and affect ratings.

As to data collection II, of the 27 participants volunteering for the study, after screening and gender matched PSQI scores, 20 participants were selected to participate in the study. Two participants withdrew their participation, and one participant did not report any dreams. Thus, the final sample of data collection II includes 17 participants (5 males, 12 females), with ages ranging from 20 to 44 ($M = 28.35$, $SD = 6.33$), who provided 133 mind-wandering and 359 dream reports and affect ratings.

Sample sizes were limited by feasibility and resource constraints (considering the time- and resource intensive data collection procedures). We did not use optional stopping for data collection but analyzed all the data from all participants who participated in all stages of the study and who provided data for each condition. Altogether, our final sample includes 32 participants (level 2) with an average of 36.53 waking, 10.25 mind-wandering, and 16.53 dream reports/ratings (level 1). This sample size follows the recommendations of Arend and Schäfer (2019) for two-level models that yields sufficient power ($\geq$0.80) for detecting medium level-1 effect sizes.

2.2. Procedure

Participants were pre-screened and selected based on a questionnaire assessing the existence of any neurological or psychiatric diagnoses, use of medications affecting the central nervous system, subjective health, and subjective sleep quality (as measured with the PSQI). The selected participants were asked to fill in a questionnaire assessing different aspects of well-being and social behaviour (not reported here).

Data collection I took place over a three-week period in the participants' everyday (home) environment. Week 1 included the collection of mind-wandering and dream reports, week 2 waking and mind-wandering reports, and week 3 waking and dream reports. Sleep was monitored with a portable sleep-tracking device (Zeo Sleep Manager, Zeo Inc., Shambroom, Fábregas, & Johnstone, 2012) during the first and third data collection week. All participants received a financial compensation of 200 €.

Data collection II took place over a two-week period: three days in the home environment, five days on an island, which also included a three-day social seclusion condition, and seven days after the island retreat in the home environment. In both settings (home environment and island) dream and mind-wandering reports were collected. Sleep was monitored with the Zeo sleep-tracking device during the data collection period. The island retreat was conducted for the purposes of another study (that investigated the effects of social seclusion on dream content; Tuominen, Olkoniemi, Revonsuo, & Valli, 2021). To this end, the participants were shipped to a university research facility on a remote island in the Turku archipelago that was almost entirely uninhabited during the study period. The participants were given single rooms for the four nights on the island. Two researchers were also present on the island for the whole study period and took care of the practicalities of the study. On the island, there was a three-day social seclusion period: the participants were asked to avoid any social contact and their laptops and other technological devices enabling online access were collected for safe keeping. The participants could spend their time in any other way as they saw fit (e.g., by reading books, playing musical instruments, taking photographs, walking around the island). Food was delivered three times a day with no social contact with the participants. All the needs, worries, and requests of the participants during the social seclusion period were communicated via a notebook. At the end of the seclusion period, the participants filled in a brief questionnaire regarding their experiences during the three-day period and the experience was debriefed. Then, the participants returned home, where they continued to provide dream and mind-wandering reports. All the participants received a financial compensation of 150 €.

At the end of the data collection periods, a final questionnaire was administered, assessing the well-being and social behaviour of the participants (not reported here).

The study was approved by the ethical review board of the University of Turku, Finland.

2.3. Materials

All the reports and affect ratings were collected using an online (Webropol) platform. The participants could write the report directly into the online platform or first use a pen-and-paper method, and then transcribe the reports into the online platform later the same day. During the island retreat (data collection II), the participants provided the reports and ratings using a pen-and-paper method only (since they did not have access to Internet) and transcribed the reports into the online platform after the island retreat. Exactly the same instructions and procedure were used for the collection of reports and affect ratings in the two data collection efforts across all three conditions—active wakefulness, mind-wandering, and dreaming.

2.3.1. Active wakefulness

Waking reports were collected during data collection I only. To collect reports of waking events and experiences unbiased by memory distortions, an experience sampling method was used. The participants were prompted by three text messages per day sent at random times within a pre-specified time window (morning: 9–12 am; day: 12–6 pm; evening: 6–11 pm) and asked to write down the events and experiences preceding the text message as accurately and truthfully as possible. Upon providing the report, the participants were asked to rate the extent to which they experienced positive affect (PA) and negative affect (NA) during the preceding waking episode using two 5-point rating scales (0 = not at all, 1 = a little, 2 = somewhat, 3 = quite a lot, 4 = very much).

2.3.2. Mind-wandering

The participants were instructed to find a place free from distraction or noise at around 10 pm in the evening, and let their mind wander freely for the duration of ten minutes. Immediately after the ten-minute mind-wandering episode, they were asked to write down their mental contents during these ten minutes as accurately and truthfully as possible. Upon providing the report, the participants were asked to rate the extent to which they experienced PA and NA during the preceding mind-wandering episode using two 5-point rating scales (0 = not at all, 1 = a little, 2 = somewhat, 3 = quite a lot, 4 = very much).

2.3.3. Dreaming

The participants were instructed to write down their dreams immediately upon (morning) awakening as accurately and truthfully as possible. Upon reporting the dream, the participants were asked to rate the extent to which they experienced PA and NA in the preceding dream episode using two 5-point rating scales (0 = not at all, 1 = a little, 2 = somewhat, 3 = quite a lot, 4 = very much).

2.3.4. External ratings of affect

All the reports were pooled and randomized. Two blind raters were instructed to content analyse—to code the affect expressed in the report as experienced by the person who provided the report—all the reports. Raters were asked to rate the affective quality of the report as a whole using the same two 5-point rating scales as used for SR: to what extent the person experienced PA (0 = not at all, 1 = a little, 2 = somewhat, 3 = quite a lot, 4 = very much) and to what extent NA (0 = not at all, 1 = a little, 2 = somewhat, 3 = quite a lot, 4 = very much). Raters were instructed to consider both the feelings explicitly expressed in the report and any implicit feelings possibly revealed by the action described or inferred from the context. If several feelings belonged to the same dimension (i.e., PA or NA), the most intense of those was to be rated. Raters worked independently. Inter-rater reliability was assessed using a two-way mixed, consistency, average-measures intra-class correlation coefficient (ICC) (Hallgren, 2012). The resulting ICC for both PA (0.825) and NA (0.858) can be considered excellent (Cicchetti, 1994). This means that affect was rated similarly across the raters and, as a result, these ER of affect were deemed suitable to test the hypotheses of the present study. The analyses were conducted using the average ratings of the two raters.

2.4. Data analysis

Data were analysed using multilevel, or mixed-effects, regression models (also known as hierarchical models; Hox, 2010) in the R statistical program (Version 4.0.2; R Core Team, 2020). These models take into account the nested structure of the data—multiple measurement occasions (i.e., reports and ratings) nested within participants—and the resulting non-independence of these measurement occasions. They also enable the analysis of a repeated measures design with a different number of measurement occasions per participant. Moreover, these models allow for between- and within-person variation simultaneously, which results in more precise estimation of standard errors of regression coefficients.

Unless otherwise stated, we specified a series of two-level (logistic) regression models, with affect ratings at level 1 and participants at level 2. To control for study (i.e., data collection 1 and 2), age, and gender, we added these as level-2 fixed predictors. In mixed model analyses a random intercept for each participant is specified, which enables each participant to have different starting level on a variable (e.g., different levels of PA and NA). Therefore, participant ID was entered as a random factor on the intercept in all models.

To control for the possible effect of social seclusion on affect ratings in study 2 (i.e., data collection II), we repeated all the analyses reported below with social seclusion as a level-1 fixed effect predictor with two levels (not secluded, secluded) as an additional control variable. Social seclusion was not a significant predictor of affect ratings in any of the models. Therefore, this variable was not included as a control predictor in the analyses reported below.

Findings were considered significant if $p < .05$. To correct for multiple testing, we applied the False Discovery Rate (FDR) correction using the function *p.adjust* from the R package *stats*. All reported confidence intervals (CIs) are 95% CIs.

For clarity and ease of reading, the specific models are reported in conjunction with respective results.

Deidentified data is available on the Open Science Framework: https://osf.io/wmb3n/

3. Results

Below, the ratings of affect in waking, mind-wandering, and dreaming *episodes* refer to SR of affect, whereas the ratings of affect in waking, mind-wandering, and dream *reports* refer to ER of affect. To address the first aim, the ratings of affect were compared between mind-wandering and dream episodes (SR) and between mind-wandering and dream reports (ER). To address the second aim, SR and ER of affect were compared across the three different conditions—active wakefulness, mind-wandering, and dreaming.

3.1. Number of reports and ratings

The main analyses comparing affect ratings during mind-wandering and dreaming are based on 328 mind-wandering episodes/reports (195 reports from data collection I and 133 reports from data collection II) and 529 dream episodes/reports (170 reports from data collection I and 359 reports from data collection II). Additional (exploratory) analyses comparing affect ratings across active wakefulness, mind-wandering, and dreaming are based on the data collected during data collection I, which also comprises 548 waking episodes/reports.

During data collection I, participants provided an average of 36.53 (SD = 3.314) waking reports, 13.00 (SD = 2.673) mind-wandering reports and 11.33 (SD = 5.354) dream reports. During data collection II, participants provided an average of 7.82 (SD = 0.393) mind-wandering reports and 21.12 (SD = 7.123) dream reports.

3.2. Prevalence of affect during mind-wandering and dreaming

A mind-wandering or dream episode was considered emotional if participants experienced at least "a little" PA or NA (i.e., rated the episode with at least 1 PA or 1 NA). Similarly, a mind-wandering or dream report was considered emotional if external judges rated the report to contain at least "a little" PA or NA (i.e., rated the episode with at least 1 PA or 1 NA). With SR, almost all the mind-wandering (97.9%) and dreaming (94.7%) episodes were rated as emotional by participants themselves. With ER, slightly more than two thirds of the mind-wandering reports (77.4%) and half of the dream reports (56.1%) were rated as emotional by the judges.

To test whether emotionality differs between conditions, we specified generalized linear mixed models (GLMM) with binomial error distribution (with logit link function) using the function *glmer* from the R package *lme4* (Bates, Maechler, Bolker, & Walker, 2015). Binomial error distribution was chosen because emotionality was a binary outcome variable (not emotional, emotional). Condition was a level-1 fixed-effect predictor with two levels (mind-wandering, dreaming). Study (i.e., data collection I and II), age, and gender were added as level-2 fixed-effect control predictors.

Results showed that, with SR, condition was a significant predictor of emotionality. Dreaming episodes were less emotional than mind-wandering episodes (see Table 1). Additionally, study was a significant predictor, with more emotional episodes in study 2 than in study 1. Similarly, with ER, condition was a significant predictor of emotionality. Dream reports were rated to be less emotional than mind-wandering reports. Additionally, gender was a significant predictor, with women's reports being rated more emotional by judges than men's reports.

3.3. Positive and negative affect experienced during mind-wandering and dreaming

Fig. 1a and Fig. 1b display the average SR of PA and NA across mind-wandering and dreaming.

To test differences between mind-wandering and dreaming conditions in the SR of PA and NA, as well as between PA and NA in the mind-wandering and dreaming conditions, we specified cumulative link mixed-effect models via Laplace approximation using the function *clmm* (with probit link function and equidistant threshold) from the R package *ordinal* (Christensen, 2019). These models take into account the ordinal nature of the outcome variables, that is, the fact that SR of PA and NA are discrete responses measured on a five-point ordinal scale from 0 to 4. Because with ER the outcome variables (average ratings of PA and NA of the two judges) were non-negative and right-skewed, with an excess of zeros—i.e., essentially a mixture of discrete and continuous variables—Tweedie generalized linear mixed models (Tweedie GLM) with gamma distribution and log link were specified using the functions *glm* and *tweedie* from the R package *statmod* (Version 1.4.35; Smyth, Hu, Dunn, Phipson, & Chen, 2020). First, we specified models in which PA and NA were the outcome variables and condition was a level-1 fixed-effect predictor with two levels (mind-wandering, dreaming). Study (i.e., data collection I and II), age, and gender were added as level-2 fixed-effect control predictors.

With SR, condition was a significant predictor of PA and NA. Dreaming episodes were associated with significantly less PA and more NA than mind-wandering episodes (see Table 2). With ER, dream reports were associated with significantly less PA than mind-wandering reports, but there were no significant differences with regard to NA. Also, women's reports were rated to contain more PA

Table 1
Differences in the Emotionality of Mind-Wandering and Dreaming Episodes (as Measured With Self-Ratings; SR) and Mind-Wandering and Dream Reports (as Measured With External Ratings; ER).

	B [CI]	*SE*	*z-value*	*p*	*adjusted p*
Outcome: Emotionality of Episode with SR					
Condition (Dreaming)	−1.557 [−2.475; −0.639]	0.468	−3.323	**<0.001**	**0.003**
Study (Data collection II)	2.136 [0.797; 3.475]	0.683	3.127	**0.002**	**0.005**
Age	−0.100 [−0.193; −0.008]	0.047	−2.125	**0.034**	0.075
Gender (Female)	0.730 [−0.502; 1.963]	0.629	1.162	0.245	0.342
Outcome: Emotionality of Report with ER					
Condition (Dreaming)	−1.157 [−1.509; −0.804]	0.180	−6.436	**<0.001**	**<0.001**
Study (Data collection II)	0.244 [−0.461; 0.950]	0.360	0.680	0.497	0.613
Age	−0.021 [−0.075; 0.033]	0.028	−0.749	0.454	0.577
Gender (Female)	0.958 [0.261; 1.656]	0.356	2.692	**0.007**	**0.019**

Note. Adjusted p-values refer to p-values corrected using the False Discovery Rate (FDR) method.

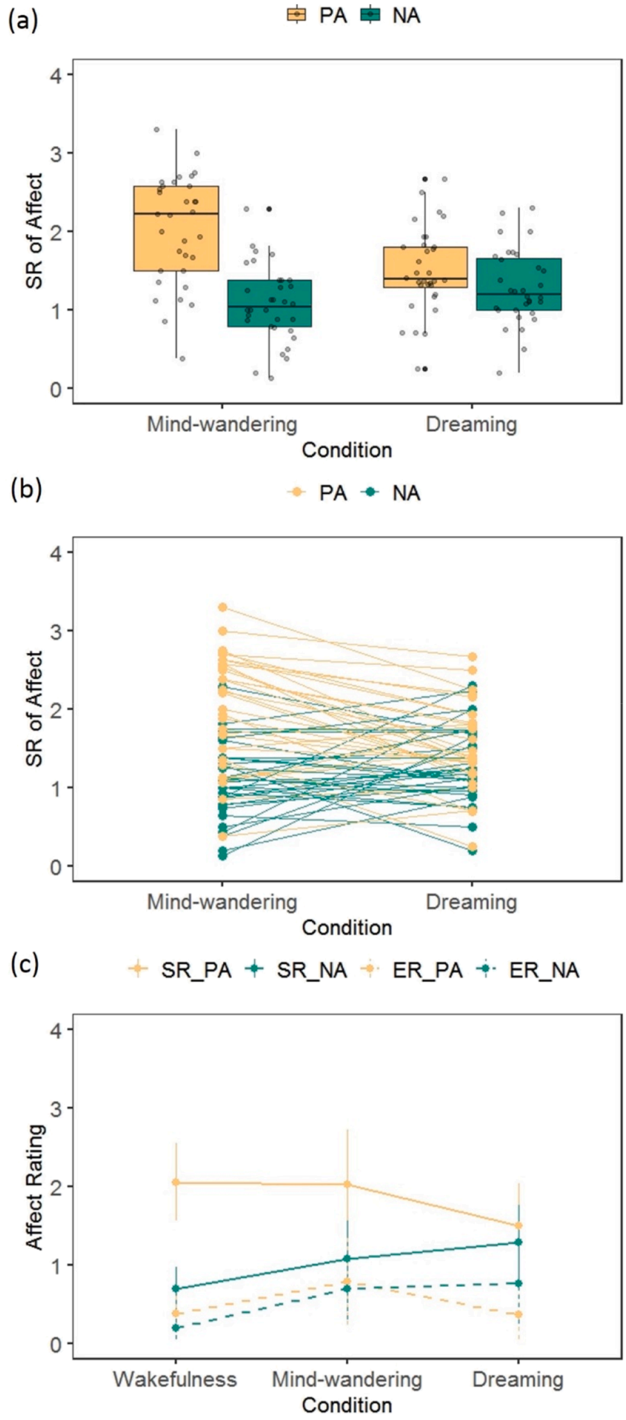

Fig. 1. Average self-ratings (SR) and external ratings (ER) of positive affect (PA) and negative affect (NA) (a) per participant, (b) separately for each participant, and (c) across the three conditions. Figures are based on 328 mind-wandering, 529 dreaming, and 548 waking reports/ratings of 32 participants (mind-wandering, dreaming) and 15 participants (active wakefulness). Error bars represent ± 1 SD.

and NA than men's reports.

Next, we specified models separately for the two conditions (mind-wandering and dreaming) in which affect rating was the outcome variable and valence as a level-1 fixed-effect predictor with two levels (negative, positive). Study (i.e., data collection I and II), age, and gender were added as level-2 fixed-effect control variables.

With SR, in both conditions (mind-wandering and dreaming), valence was a significant predictor of affect ratings. Both mind-

Table 2
Differences in Positive Affect (PA) and Negative Affect (NA) Between Mind-Wandering and Dreaming Conditions as Measured with Self-Ratings (SR) and External Ratings (ER).

	B [CI]	*SE*	*z-value*	*p*	*adjusted p*
Outcome: SR PA					
Condition (Dreaming)	−0.589 [−0.745; −0.432]	0.080	−7.380	**<0.001**	**<0.001**
Study (Data collection II)	−0.049 [−0.453; 0.354]	0.206	−0.240	0.810	0.851
Age	−0.030 [−0.061; 0.001]	0.016	−1.881	0.060	0.124
Gender (Female)	0.211 [−0.189; 0.612]	0.205	1.032	0.302	0.409
Outcome: SR NA					
Condition (Dreaming)	0.238 [0.081; 0.395]	0.080	2.974	**0.003**	**0.008**
Study (Data collection II)	0.195 [−0.108; 0.498]	0.155	1.261	0.207	0.315
Age	−0.004 [−0.027; 0.019]	0.012	−0.314	0.754	0.808
Gender (Female)	0.178[−0.122; 0.478]	0.153	1.165	0.244	0.342
Outcome: ER PA					
Condition (Dreaming)	−0.388 [−0.497; −0.279]	0.056	−6.984	**<0.001**	**<0.001**
Study (Data collection II)	0.024 [−0.089; 0.137]	0.057	0.430	0.668	0.747
Age	0.000 [−0.008; 0.009]	0.004	0.115	0.908	0.926
Gender (Female)	0.323 [0.216; 0.430]	0.054	5.972	**<0.001**	**<0.001**
Outcome: ER NA					
Condition (Dreaming)	0.033 [−0.083; 0.147]	0.057	0.567	0.571	0.677
Study (Data collection II)	0.065 [−0.050; 0.180]	0.058	1.119	0.263	0.362
Age	−0.005 [−0.014; 0.003]	0.004	−1.247	0.213	0.315
Gender (Female)	0.315 [0.206; 0.422]	0.056	5.629	**<0.001**	**<0.001**

Note. Adjusted p-values refer to p-values corrected using the False Discovery Rate (FDR) method.

wandering and dreaming episodes were associated with more positive than negative valence (i.e., more PA than NA) (see Table 3). Age was a significant predictor of affect ratings in the dreaming condition, with older participants rating their dream episodes to be lower in affect than younger participants.

With ER, dream reports were associated with less PA than NA, whereas for mind-wandering reports PA and NA did not differ. Gender was a significant predictor of affect ratings, with women's mind-wandering and dream reports judged to contain more affect than the reports of men.

3.4. Prevalence and valence of affect across active wakefulness, mind-wandering, and dreaming

In a sub-sample (data collected during data collection I, i.e., 913 reports of 15 participants) we conducted exploratory analyses to compare waking affect to that experienced during mind-wandering and dreaming episodes and expressed in mind-wandering and dream reports.

With SR almost all the waking episodes (96.5%, $N = 548$) were rated as emotional by participants themselves, whereas less than half of the waking reports (39.9%) were rated as emotional by the judges.

Table 3
Differences Between the Ratings of Positive Affect (PA) and Negative Affect (NA) During Mind-Wandering and Dreaming as Measured with Self-Ratings (SR) and External Ratings (ER).

	B [CI]	*SE*	*z-value*	*p*	*adjusted p*
Outcome: Affect rating with SR; Condition mind-wandering					
Valence (Positive)	1.022 [0.849; 1.195]	0.088	11.569	**<0.001**	**<0.001**
Study (Data collection II)	−0.089 [−0.404; 0.226]	0.161	−0.554	0.579	0.678
Age	−0.006 [−0.030; 0.019]	0.013	−0.447	0.655	0.741
Gender (Female)	0.370 [0.054; 0.686]	0.161	2.294	**0.022**	0.052
Outcome: Affect rating with SR; Condition dreaming					
Valence (Positive)	0.160 [0.032; 0.288]	0.065	2.446	**0.015**	**0.037**
Study (Data collection II)	0.199 [−0.050; 0.449]	0.127	1.565	0.118	0.216
Age	−0.024 [−0.043; −0.005]	0.010	−2.431	**0.015**	**0.038**
Gender (Female)	0.071 [−0.176; 0.319]	0.126	0.565	0.572	0.677
Outcome: Affect rating with ER; Condition mind-wandering					
Valence (Positive)	0.045 [−0.150; 0.239]	0.099	0.452	0.652	0.741
Study (Data collection II)	−0.102 [−0.305; 0.103]	0.105	−0.980	0.328	0.433
Age	−0.005 [−0.020; 0.010]	0.008	−0.674	0.500	0.613
Gender (Female)	0.748 [0.545; 0.949]	0.103	7.247	**<0.001**	**<0.001**
Outcome: Affect rating with ER; Condition dreaming					
Valence (Positive)	−0.776 [−0.989; −0.562]	0.109	−7.133	**<0.001**	**<0.001**
Study (Data collection II)	0.225 [−0.017; 0.459]	0.121	1.858	0.063	0.128
Age	−0.002 [−0.021; 0.018]	0.009	−0.228	0.820	0.853
Gender (Female)	0.529 [0.307; 0.747]	0.113	4.667	**<0.001**	**<0.001**

Note. Adjusted p-values refer to p-values corrected using the False Discovery Rate (FDR) method.

To test whether emotionality differs between conditions, we specified generalized linear mixed models (GLMM) with binomial error distribution (with logit link function) with emotionality as the binary outcome variable (not emotional, emotional) and condition as a level-1 fixed-effect predictor with three levels (active wakefulness, mind-wandering, dreaming). As with the main analyses, age and gender were entered as level-2 fixed-effect control predictors.

With SR, dreaming episodes were associated with less emotionality than waking episodes ($B = -1.424$, 95% CI [−2.146; −0.702], $SE = 0.368$, $z = -3.865$, FDR-adjusted $p < .001$), whereas the emotionality of mind-wandering episodes did not differ from that of waking episodes ($B = 0.014$, 95% CI [−0.893; 0.922], $SE = 0.463$, $z = 0.031$, FDR-adjusted $p = .980$). With ER, both mind-wandering ($B = 1.576$, 95% CI [1.190; 1.963], $SE = 0.197$, $z = 7.986$, FDR-adjusted $p < .001$) and dream ($B = 0.622$, 95% CI [0.252; 0.992], $SE = 0.189$, $z = 3.292$, FDR-adjusted $p = .003$) reports were associated with more emotionality than waking reports.

To test differences in PA and NA between conditions, for SR outcomes we specified cumulative link mixed-effect models via Laplace approximation using the function *clmm* (with probit link function and equidistant threshold), whereas for ER outcomes we specified Tweedie generalized linear mixed models (Tweedie GLM) with gamma distribution and log link using the functions *glm* and *tweedie* First, we specified models where PA and NA were the outcome variables, condition was a level-1 fixed-effect predictor with three levels (active wakefulness, mind-wandering, dreaming), and age and gender as level-2 fixed-effect control predictors.

With SR, dreaming episodes were associated with lower levels of PA as compared to waking episodes ($B = -0.578$, 95% CI [−0.764; −0.391], $SE = 0.095$, $z = -6.060$, FDR-adjusted $p < .001$), whereas PA in mind-wandering episodes did not significantly differ from that in the waking episodes ($B = -0.033$, 95% CI [−0.206; 0.139], $SE = 0.088$, $z = -0.380$, FDR-adjusted $p = .780$). At the same time, dreaming ($B = 0.536$, 95% CI [0.342; 0.731], $SE = 0.099$, $z = 5.406$, FDR-adjusted $p < .001$) and mind-wandering ($B = 0.477$, 95% CI [0.295; 0.658], $SE = 0.093$, $z = 5.144$, FDR-adjusted $p < .001$) episodes were associated with higher levels of NA than waking episodes.

With ER, mind-wandering reports had higher levels of PA as compared to waking reports ($B = 0.611$, 95% CI [0.307; 0.929], $SE = 0.156$, $z = 3.904$, FDR-adjusted $p < .001$), whereas dream reports and waking reports did not differ ($B = -0.240$, 95% CI [−0.556; 0.093], $SE = 0.165$, $z = -1.459$, FDR-adjusted $p = .308$). Both mind-wandering reports ($B = 1.329$, 95% CI [0.963; 1.719], $SE = 0.192$, $z = 6.941$, FDR-adjusted $p < .001$) and dream reports ($B = 1.114$, 95% CI [0.730; 1.525], $SE = 0.202$, $z = 5.520$, FDR-adjusted $p < .001$) had higher levels of NA than waking reports.

Next, we tested differences between PA and NA in the waking condition. Affect rating was the outcome variable, valence was the level-1 fixed-effect predictor with two levels (negative, positive), and age and gender as level-2 fixed-effect control predictors.

Both, SR of waking episodes ($B = 1.511$, 95% CI [1.367; 1.656], $SE = 0.073$, $z = 20.556$, FDR-adjusted $p < .001$) and ER of waking reports ($B = 0.738$, 95% CI [0.459; 1.017], $SE = 0.139$, $z = 5.326$, FDR-adjusted $p < .001$) were associated with more positive than negative valence (i.e., more PA than NA).

3.5. Comparison of self-and external ratings of affect

Comparison of SR and ER of affect are based on data obtained during the two data collection efforts, that is, 548 waking episodes/reports (from data collection I, 15 participants), 328 mind-wandering episodes/reports (data collection I and II, 32 participants), and 529 dream episodes/reports (data collection I and II, 32 participants). Fig. 1c displays the average SR and ER of PA and NA across the three conditions.

To test differences in emotionality between SR and ER, generalized linear mixed models (GLMM) with binomial error distribution (with logit link function) were specified. Models were run separately for the three conditions: active wakefulness, mind-wandering, and dreaming. Emotionality was the binary outcome variable (not emotional, emotional) and rating type as the level-1 fixed-effect predictor with two levels (SR, ER). Study (i.e., data collection I, II), age and gender were level-2 fixed-effect control predictors.

In all three conditions—active wakefulness, mind-wandering, and dreaming—rating type was a significant predictor of emotionality, with ER being associated with lower emotionality ratings than SR (see Table 4).

For the outcome variables PA and NA, Tweedie generalized linear mixed models (Tweedie GLM) with gamma distribution and log

Table 4
Differences Between Self-Ratings (SR) and External Ratings (ER) in Emotionality Across Active Wakefulness, Mind-Wandering, and Dreaming.

	B [CI]	*SE*	*z-value*	*p*	*adjusted p*
Outcome: Emotionality; Condition: Active wakefulness					
Rating type (ER)	−4.013 [−4.535; −3.491]	0.266	−15.074	**<0.001**	**<0.001**
Age	0.027 [−0.034; 0.088]	0.031	0.857	0.391	0.510
Gender (Female)	0.565 [−0.180; 1.309]	0.379	1.487	0.137	0.248
Outcome: Emotionality; Condition: Mind-wandering					
Rating type (ER)	−2.956 [−3.802; −2.110]	0.432	−6.848	**<0.001**	**<0.001**
Study (Data collection II)	0.659 [−0.352; 1.671]	0.516	1.277	0.202	0.315
Age	−0.020 [−0.100; 0.060]	0.041	−0.499	0.618	0.715
Gender (Female)	1.794 [0.794; 2.794]	0.510	3.516	**<0.001**	**0.001**
Outcome: Emotionality; Condition: Dreaming					
Rating type (ER)	−2.860 [−3.297; −2.423]	0.223	−12.821	**<0.001**	**<0.001**
Study (Data collection II)	0.487 [−0.202; −1.177]	0.352	1.385	0.166	0.285
Age	−0.047 [−0.100; 0.005]	0.027	−1.767	0.077	0.147
Gender (Female)	0.613 [−0.074; 1.299]	0.350	1.749	0.080	0.150

Note. Adjusted p-values refer to p-values corrected using the False Discovery Rate (FDR) method.

link were specified using the functions *glm* and *tweedie*. Rating type was the level-1 fixed-effect predictor with two levels (SR, ER). Study (i.e., data collection I, II), age and gender were level-2 fixed-effect control predictors.

Results showed that rating type was a significant predictor of PA and NA. ER, as compared to SR, was associated with less PA and NA across all three conditions—active wakefulness, mind-wandering, and dreaming (see Table 5).

To explore associations between SR and ER, we specified Tweedie generalized linear mixed models (Tweedie GLM) with gamma distribution and log link using the functions *glm* and *tweedie* separately for PA and NA for each of the three conditions (active wakefulness, mind-wandering, and dreaming). SR of PA and SR of NA were the ordinal outcome variables, ER of PA and ER of NA were the level-1 fixed-effect predictors. Study (i.e., data collection I, II), age and gender were level-2 fixed-effect control predictors.

SR of PA and ER of PA were positively associated in active wakefulness ($B = 0.326$, 95% CI [0.258; 0.395], $SE = 0.035$, $z = 9.326$, $p < .001$), mind-wandering ($B = 0.265$, 95% CI [0.178; 0.352], $SE = 0.044$, $z = 5.960$, $p < .001$) and dreaming ($B = 0.304$, 95% CI [0.233; 0.375], $SE = 0.036$, $z = 8.401$, $p < .001$) conditions. Similarly, SR of NA and ER of NA were positively associated in active wakefulness ($B = 0.576$, 95% CI [0.471; 0.680], $SE = 0.053$, $z = 10.805$, $p < .001$), mind-wandering ($B = 0.362$, 95% CI [0.284; 0.440], $SE = 0.040$, $z = 9.107$, $p < .001$) and dreaming ($B = 0.290$, 95% CI [0.239; 0.341], $SE = 0.026$, $z = 11.133$, $p < .001$) conditions. Level-1 Spearman correlations between SR and ER for PA were $r_s = 0.301$, $p < .001$ (wakefulness), $r_s = 0.347$, $p < .001$ (mind-wandering), and $r_s = 0.296$, $p < .001$ (dreaming), whereas for NA they were $r_s = 0.424$, $p < .001$ (wakefulness), $r_s = 0.476$, $p < .001$ (mind-wandering), and $r_s = 0.493$, $p < .001$ (dreaming).

4. Discussion

We investigated the within-person dynamics of affective experiences across the wake-sleep cycle. First, we compared waking mind-wandering and night-time dreaming with regard to the prevalence and valence of affect. Second, we compared self-ratings (SR; participants' own ratings of affect in the preceding *episode* of experience) and external ratings (ER; ratings of affect based on the verbal description of the same experiences in narrative reports) of affect across the active wakefulness, mind-wandering (i.e., resting wakefulness), and dreaming conditions.

4.1. Affect experienced during waking mind-wandering and night-time dreaming

Results showed that, irrespective of the measurement method, dreaming episodes and dream reports were less emotional, and specifically less positive, than mind-wandering episodes and reports. However, whereas with SR dream episodes were more negative than mind-wandering episodes, with ER there were no differences in negative affectivity between dream reports and mind-wandering reports. Whereas with SR both mind-wandering and dreaming episodes were positively biased (i.e., more PA than NA), with ER mind-

Table 5
Differences Between Self-Ratings (SR) and External Ratings (ER) in Positive Affect (PA) and Negative Affect (NA) Ratings Across Wakefulness, Mind-Wandering, and Dreaming.

	B [CI]	*SE*	*z-value*	*p*	*adjusted p*
Outcome: PA; Condition: Active wakefulness					
Rating type (ER)	−1.515 [−1.670; −1.360]	0.079	−19.175	**<0.001**	**<0.001**
Age	−0.008 [−0.021; 0.005]	0.007	−1.266	0.206	0.315
Gender (Female)	0.055 [−0.103; 0.214]	0.081	0.683	0.495	0.613
Outcome: PA; Condition: Mind-wandering					
Rating type (ER)	−1.495 [−1.694; −1.297]	0.101	−14.790	**<0.001**	**<0.001**
Study (Data collection II)	0.141 [−0.068; 0.351]	0.107	1.321	0.187	0.308
Age	−0.015 [−0.031; 0.001]	0.008	−1.800	0.072	0.141
Gender (Female)	0.105 [−0.103; 0.312]	0.106	0.990	0.323	0.432
Outcome: PA; Condition: Dreaming					
Rating type (ER)	−1.079 [−1.225; −0.933]	0.074	−14.508	**<0.001**	**<0.001**
Study (Data collection II)	0.009 [−0.152; 0.172]	0.083	0.119	0.905	0.926
Age	−0.007 [−0.019; 0.005]	0.006	−1.203	0.229	0.333
Gender (Female)	0.155 [0.003; 0.307]	0.077	2.001	**0.046**	0.098
Outcome: NA; Condition: Active wakefulness					
Rating type (ER)	−1.330 [−1.569; −1.091]	0.122	−10.922	**<0.001**	**<0.001**
Age	0.020 [0.000; 0.040]	0.010	1.984	**0.048**	0.100
Gender (Female)	0.517 [0.273; 0.761]	0.125	4.150	**<0.001**	**<0.001**
Outcome: NA; Condition: Mind-wandering					
Rating type (ER)	−0.437 [−0.607; −0.267]	0.087	−5.044	**<0.001**	**<0.001**
Study (Data collection II)	−0.108 [−0.288; 0.072]	0.092	−1.178	0.239	0.342
Age	−0.000 [−0.014; 0.014]	0.007	−0.026	0.980	0.980
Gender (Female)	0.443 [0.266; 0.621]	0.091	4.897	**<0.001**	**<0.001**
Outcome: NA; Condition: Dreaming					
Rating type (ER)	−0.548 [−0.685; −0.412]	0.069	−7.872	**<0.001**	**<0.001**
Study (Data collection II)	0.277 [0.126; 0.429]	0.077	3.583	**<0.001**	**0.001**
Age	−0.011 [−0.022; 0.001]	0.006	−1.834	0.067	0.133
Gender (Female)	0.307 [0.165; 0.449]	0.072	4.235	**<0.001**	**<0.001**

Note. Adjusted p-values refer to p-values corrected using the False Discovery Rate (FDR) method.

wandering reports had a balanced affective tone (i.e., similar ratings of PA and NA) but dream reports were negatively biased (i.e., more NA than PA). Together, these results confirm our hypothesis of mind-wandering being relatively more positively valenced than dreaming. These findings are in line with previous studies that have compared SR of affect experienced during mind-wandering and dream episodes (Carr & Nielsen, 2015; Carr et al., 2016; Gross et al., 2021) but stand in contrast to a study that compared ER of affect in mind-wandering and night-time dream reports (Perogamvros et al., 2017). However, it is important to note that in the latter study, the authors only analysed so-called high-thought mind-wandering and dream reports, which may explain differences in the results.

Additionally, exploratory analyses including all three conditions showed that, regardless of the measurement method, waking experiences were also positively biased (i.e., more PA than NA) and that negative affect increased from wakefulness to mind-wandering to dreaming. Thus, across the wake-sleep cycle, positive affect decreases, while negative affect increases. Studies comparing affect in active wakefulness and dreams have reached similar conclusions (Conte et al., 2020; Nielsen et al., 1991). In fact, there is abundant evidence that in waking life people generally experience mild to moderate PA, or more PA than NA (Diener et al., 2015, 2018). This means that PA is the default in healthy individuals unless aversive stimuli evoke NA (Diener, Kanazawa, Suh, & Oishi, 2015). The current study, together with previous studies (Fox et al., 2018), demonstrates that this positivity bias also extends to mind-wandering, at least with respect to SR of affect.

Although dream episodes and reports were rated to be less positive and more negative than waking (active wakefulness and mind-wandering) episodes and reports, results regarding the overall affective tone of dreaming depended on whether SR or ER of affect were used.

4.2. Self- vs external ratings of affect across the wake-sleep cycle

With SR, all the episodes and reports across the three conditions—active wakefulness, mind-wandering, and dreaming—were rated as more emotional, more positive, and less negative than with ER. These results confirm our hypotheses and fit well with existing studies showing how our methods of measurement influence the results regarding dream affectivity (Kahan & LaBerge, 1996; Röver & Schredl, 2017; Schredl & Doll, 1998; Sikka et al., 2014, 2017). Our findings go beyond existing evidence by demonstrating that the same discrepancies also apply to the measurement of affect during mind-wandering and active wakefulness. Importantly, although SR and ER of PA and NA were positively associated, the two methods can lead to entirely different conclusions about the affective nature of our experiences across different states of consciousness. When participants themselves rate affect, their experiences across all three states of consciousness can be considered inherently emotional and positively biased, although the positivity bias decreases across the wake-sleep cycle. However, when participants' verbal descriptions of affective experiences in narrative reports are analysed, affect can be absent from one third to more than half of the reports and affective valence changes from positively biased waking reports to affectively balanced mind-wandering reports to negatively biased dream reports.

4.3. Theoretical and empirical implications

According to the dynamic framework of spontaneous thought (Christoff et al., 2016), mind-wandering is an intermediate state between waking goal-directed thought and dreaming. The results of the current study provide support for this framework. Although affect experienced during mind-wandering differed from affect experienced in active wakefulness and dreaming, it shared qualitative features with both states. Moreover, there was a continuous transition in the affective quality of experiences: the positivity bias (i.e., more PA than NA) characteristic to waking experiences and reports gradually decreased across the wake-sleep continuum.

These findings cannot be fully explained by the incorporation continuity hypothesis (Schredl & Hofmann, 2003; Schredl, 2003). If dream experiences merely reflect waking events and experiences, the overall affective quality should be similar in wakefulness and dreaming. The theory, thus, cannot account for the decreasing positivity bias. The neurocognitive theory, which considers dreaming to be an intensified form of mind-wandering (Domhoff & Fox, 2015; Domhoff, 2018), is partially supported. Whereas negative affect was indeed more intense during dreaming as compared to mind-wandering, positive affect was less intense. Thus, the intensification was selective for negative affect only. The threat simulation theory, which proposes that dreams selectively simulate threatening experiences (Revonsuo, 2000; Valli & Revonsuo, 2009), is also partially supported. Across the sleep-wake cycle NA indeed increased (with SR) and PA decreased. However, the negativity bias only applied to ER of dream affect (i.e., when verbal descriptions of affective experiences were analysed), but not to SR of dream affect (i.e., when participants themselves rated their affective experiences). These findings raise the question as to what explains the change in the valence of affective experiences across the wake-sleep cycle. In the following section we offer a possible neurobiological explanation.

4.3.1. The neural basis of decreasing positivity bias across the wake-sleep continuum

It is widely established that mind-wandering involves the default-mode network (DMN), a set of interconnected brain areas including the medial prefrontal cortex (PFC; including the rostromedial PFC, ventromedial PFC, dorsomedial PFC), medial parietal cortex/posterior cingulate cortex, lateral and inferior parietal cortex/temporoparietal junction, and lateral and medial temporal cortices (Andrews-Hanna, Smallwood, & Spreng, 2014; Buckner, Andrews-Hanna, & Schacter, 2008; Fox, Spreng, Ellamil, Andrews-Hanna, & Christoff, 2015; Gusnard & Raichle, 2001). It is often less acknowledged that mind-wandering also involves regions of the frontoparietal control network (FPCN), such as the right lateral PFC, right anterior inferior parietal lobule, dorsal anterior cingulate cortex, and precuneus. The FPCN plays an important role in executive control, including goal-directed thought (Fox et al., 2015). FPCN regions are functionally connected with DMN regions and have been suggested to play an important role in the regulation of DMN, and as such, in the monitoring and control of internally generated subjective experiences (Andrews-Hanna et al., 2014; Dixon et al., 2018;

Fox et al., 2015).

Both DMN and FPCN are involved in affective processing. The ventromedial PFC (including the medial orbitofrontal cortex), a central node of the DMN, is known to play a role in tracking and appraising the affective significance of internally generated experiences, and as such, representing the affective valence of these subjective experiences (Dixon, Thiruchselvam, Todd, & Christoff, 2017; Lindquist, Satpute, Wager, Weber, & Barrett, 2016; Ochsner, Silvers, & Buhle, 2012; Tusche, Smallwood, Bernhardt, & Singer, 2014). Evidence indicates that other DMN nodes are also consistently activated during affective experiences (for a review, see Satpute & Lindquist, 2019). This is enabled by the interaction between the DMN and the salience network, another large-scale brain network including cortical (e.g., anterior insula, dorsal anterior cingulate cortex) and subcortical (e.g., amygdala, ventral striatum) areas involved in the generation and processing of affect (see Seeley, 2019 for a review). As to FPCN, there is abundant evidence for its role in the regulation of affect (Dixon et al., 2017; Etkin, Büchel, & Gross, 2015; Ochsner et al., 2012). Specifically, it has been suggested that lateral PFC regions regulate affect by modulating the salience network (especially the subcortical brain areas) via the ventromedial PFC (Ochsner et al., 2012). Thus, effective affect regulation entails relatively more activity in the lateral PFC as compared to ventromedial PFC, and relatively more activity in the ventromedial PFC as compared to subcortical affect-related brain areas.

Although DMN remains active during sleep, its connectivity gradually decreases across non-REM sleep stages and breaks down in the deepest sleep stage (slow-wave sleep), the sleep stage least associated with dream experiences (Sämann et al., 2011). During REM sleep—the sleep stage most associated with having vivid dream experiences— the DMN as well as the salience network are (re) activated, even to a higher degree than during resting wakefulness. Lesions to key regions of the DMN, specifically to ventromedial PFC, cause the cessation of dreaming (Solms, 2000). Electrophysiological studies have shown that the presence of dream experiences (as compared to not having any dream experiences) is associated with activation of the posterior DMN regions, such as the posterior cingulate cortex, in different sleep stages (Siclari et al., 2017, 2018). Moreover, dream recall is associated with increased DMN connectivity (Vallat, Nicolas, & Ruby, 2020). Thus, mind-wandering and dreaming both involve the activation of DMN regions. However, there is a continuous decrease of activity of the FPCN from active wakefulness to mind-wandering to sleep (Fox et al., 2013; Muzur, Pace-Schott, & Hobson, 2002).

Based on the above, we propose that the affective valence of spontaneous experiences may depend on the dynamic interaction of these three intrinsic networks (see also Dixon & Gross, 2021; Christoff et al., 2016). Activation of DMN areas may underlie the stream of ongoing subjective experiences, the affective valence of which is contributed by the salience network, whereas the higher-order executive control areas help regulate the affective quality of the experiences and maintain their positive valence. Altered activation and connectivity of DMN areas without the accompanying activation, and regulation, of executive-control areas may underlie negatively valenced subjective experiences. In fact, research shows that depressive rumination as well as anxious worry are associated with hyperactivity of DMN, or hyperconnectivity within DMN or between DMN and other networks (e.g., the salience network) and with reduced cognitive control by the FPCN regions (Andrews-Hanna et al., 2014; Dixon et al., 2018; Zhou et al., 2020).

In active wakefulness, when we are focused on some external task, the FPCN is typically more activated than DMN. This can explain the positivity bias characteristic to waking affect. During sleep, especially during REM sleep, activity of the FPCN is decreased and this may underlie the lower positivity (or higher negativity) of dream experiences. In fact, we have previously demonstrated that reduced activity over the right frontal cortical areas (areas belonging to the FPCN) during REM sleep is associated with experiencing more anger in concurrent dreams (Sikka, 2019). Thus, the less the FPCN is activated, the more negative the dream content. This is further supported by research on lucid dreaming during which people are aware that they are dreaming. Lucid dreaming is characterized by insight and cognitive control which is supported by the activation of brain areas belonging to the FPCN (for a review, see Baird, Mota-Rolim, & Dresler, 2019). As a result, lucid dreams are also more positively valenced than non-lucid dreams (Stocks et al., 2020; Voss, Schermelleh-Engel, Windt, Frenzel, & Hobson, 2013).

One may ask, why would the FPCN help maintain a positivity bias in (active and resting) wakefulness. From an evolutionary perspective, affective reactions are adaptations that have evolved to help us respond appropriately to various opportunities and challenges (Nesse, 2005). For healthy individuals, the positivity bias in wakefulness occurs in the absence of threats and has been suggested to underlie approach behaviour, such as exploring the environment and communicating with other members of the social group (Cacioppo & Berntson, 1994, 1999; Diener et al., 2015). Similarly, positively valenced mind-wandering, which is associated with future-oriented thoughts, helps simulate possible future events and plan the best course of action, and as such, underlies problem-solving and creativity (e.g., Smallwood & Andrews-Hanna, 2013; Spronken, Holland, Figner, & Dijksterhuis, 2016). Thus, the positivity bias in active wakefulness and mind-wandering may be an important adaptation supported by the lateral PFC (which is also evolutionarily and developmentally the latest region to mature) ensuring that individuals behave in ways that are beneficial for survival and reproductive success. In fact, the above-neutral offset for PA is similar to the phenomena of positive illusions (Taylor & Brown, 1994) and optimism bias (Sharot, 2011), all of which have been found to underlie psychological well-being. This indicates that a fully realistic perception of the world is not necessarily evolutionarily adaptive and beneficial for well-being. At the same time, it is important to emphasize that excessive positivity is not adaptive either and can even be detrimental (Nesse, 2005).

During sleep, when we are mostly disconnected from the external environment and the brain is busy processing acquired memories, maintaining a positivity bias per se is not evolutionarily important. This is especially true when sleeping in a safe environment. This would help explain the more affectively balanced dream experiences. In fact, the threat simulation theory predicts that dream experiences have a negativity bias, because dreaming has been selected for the ability to simulate adaptively important dangerous events (Revonsuo, 2000). This bias is supposed to pervade dream experiences in general (just like the positivity bias characterizes waking experiences), but the negativity bias in dreams has been shown to become even higher if the threat simulation system has been activated by real dangers and stressors in waking life (Lafrenière, Lortie-Lussier, Dale, Robidoux, & De Koninck, 2018; Valli et al., 2005, 2006).

In summary, the positivity bias in wakefulness is evolutionarily adaptive, and it is maintained by relatively more activity of the FPCN, as compared to the DMN and the salience network. Across the sleep-wake cycle, as the activity of the FPCN decreases, while DMN and the salience network remain activated, the positvity bias decreases.

4.3.2. Self-Ratings of affective experiences and verbal descriptions of affective experiences do not reflect the same underlying phenomenon

Both SR of affect and verbal descriptions of affect are generally assumed to reflect underlying affective experiences (e.g., Fan et al., 2019). Although in the current study SR and ER were positively associated, the correlations were too low ($r = 0.296–0.493$, indicating 9–24% shared variance) to demonstrate adequate convergent validity (Carlson & Herdman, 2012). This has also been demonstrated in previous studies on waking (e.g., Kross et al., 2019; Sun et al., 2020; Tov et al., 2013) and dream affect (see Sikka, 2020 for an overview). Low convergent validity can result in substantial differences in research findings and their interpretation (Carlson & Herdman, 2012). As shown in this study, across the wake-sleep cycle, both methods of measurement indicated a similar dynamics of change—a decrease in positivity bias. However, within each state (i.e., active wakefulness, mind-wandering, dreaming), the two measures led to entirely different conclusions about the affective nature of our experiences. Thus, although SR and verbal descriptions of affective experiences overlap to some extent, the overlap is of too low magnitude to assume that they reflect exactly the same underlying phenomenon.

On the one hand, verbal descriptions of affective experiences may not adequately capture affective experiences since the descriptions may be selective (e.g., describing what was going on, rather than what a person was feeling) and influenced by various individual differences (e.g., language and introspection skills) (Kahan & LaBerge, 1996). It has been suggested that such verbal descriptions reflect only the most salient or intense affective experiences (Sikka et al., 2018; Vine, Boyd, & Pennebaker, 2020), one's attention to affective experiences (Boyd & Schwartz, 2021) or familiar affective states (Vine et al., 2020).

On the other hand, SR may also be vulnerable to various biases, such as response biases (Paulhus & Vazire, 2007) and participants' presuppositions and beliefs about their experiences (Heavey, Hurlburt, & Lefforge, 2012). Memory biases can also exert an influence, although the use of experience sampling (active wakefulness) and minimizing the gap between the experience and the ratings (mind-wandering, dreaming), as done in the current study, would arguably reduce such biases. Also, it has been shown that SR of affect in wakefulness are positively associated with informant ratings (Diener, Smith, & Fujita, 1995) and that response biases have only a minor influence on SR of affect (Schimmack, Böckenholt, & Reisenzein, 2002) which would provide support for the validity of SR.

Thus, it could be that either one of the methods is a more valid indicator of subjective affective experience or both methods capture some aspects of the experience that neither alone can. Therefore, more multimethod research (using various self-report measures together with informant ratings as well as with behavioural and psychophysiological measures) is clearly needed to carve out the convergence and divergence of SR and ER of affect so as to better understand to what extent these reflect the subjective experience of affect.

4.4. Limitations and future directions

In the current study we used a mind-wandering task, which can be considered intentional mind-wandering. Different forms of mind-wandering (e.g., intentional vs unintentional) may be associated with different affective quality and, at least partly, distinct neural correlates (Seli et al., 2017, 2018). Also, other aspects of mind-wandering, such as temporal bias (i.e., whether thoughts are past-, present-, or future-oriented) and sensory modality, may influence the affective valence of mind-wandering (Fox et al., 2018). Furthermore, mind-wandering may have also occurred during so-called active wakefulness (i.e., when participants were prompted to report and rate their waking events and experiences prior to receiving a signal). All this may have led to more similarity between wakefulness and mind-wandering than would have otherwise been the case. However, given that our results corroborate those of Gross et al. (2021), who used experience sampling and differentiated stimulus-dependent thoughts (active wakefulness) and stimulus-independent thoughts (mind-wandering), gives credence to our findings and indicates that the positivity bias applies to active wakefulness as well as to intentional and spontaneous mind-wandering. Nevertheless, it would be important to compare the affective quality of different forms and aspects of mind-wandering with that of dreaming.

The timing of data collection should also be considered. The mind-wandering task was carried out late in the evening and reports/ratings of dream affect were obtained upon morning awakening. This means that the results apply to late night mind-wandering and late night/early morning dreams. Since the time of night has been shown to influence dream affect (Sikka, Revonsuo, Sandman, Tuominen, & Valli, 2018), it may well be that the results would be different with dreams sampled from different times of night (and from different sleep stages) (Sikka, 2019). Future research should thus investigate affective experiences across ultradian (i.e., short cycles oscillating within a 24-hour period) and circadian (i.e., approximately 24-hour cycle) cycles during the day and night.

The present study included a sample of healthy young adults. It is known that the positivity bias in wakefulness is lower in those suffering from depression (Gollan et al., 2016), and that people with trait negative affect or symptoms of various mental health disorders report more negative mind-wandering (Fox et al., 2018) and dreams (Levin & Nielsen, 2007). Therefore, it is important to study individual differences and variability in the affective quality of subjective experiences.

Finally, research on waking affect, mind-wandering, and dreaming has developed rather independently. Given that affective experiences occur throughout the wake-sleep continuum, we cannot neglect those taking place in one behavioural state or another. While there is significant amount of research on the neural basis of affective experiences in wakefulness, we know less about the neural basis of affective experiences during mind-wandering, and very little about the neural underpinnings of dream affect. Thus, to understand the dynamics of affective experiences across the wake-sleep cycle, we need to study not only the phenomenology but also the neural basis of these experiences at a within person level.

5. Conclusion

In summary, this study demonstrates that across the wake-sleep continuum—from active wakefulness to mind-wandering to dreaming—the positivity bias characteristic to waking experiences decreases. If measured by self-ratings, both mind-wandering and dreaming are positively biased. If verbal descriptions of affective experiences are analysed, mind-wandering has a more balanced affective tone and dreaming is negatively biased. Thus, conclusions regarding the affective nature of subjective experiences depend on which method of measurement is used. To understand the dynamics of affective experiences across the wake-sleep cycle both on the phenomenal as well as neurobiological level, more integration between the fields of emotion research, mind-wandering research, and dream research is needed.

CRediT authorship contribution statement

Pilleriin Sikka: Conceptualization, Methodology, Writing – original draft, Funding acquisition, Formal analysis, Visualization. **Katja Valli:** Conceptualization, Methodology, Writing – review & editing. **Antti Revonsuo:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition. **Jarno Tuominen:** Conceptualization, Methodology, Writing – review & editing, Funding acquisition, Investigation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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