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Comparing the phenomenological qualities of stimulus-independent thought, stimulus-dependent thought and dreams using experience sampling

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Humans spend a considerable portion of their lives engaged in 'stimulus-independent thoughts' (SIT), or mental activity that occurs independently of input from the immediate external environment. Although such SITs are, by definition, different from thoughts that are driven by stimuli in one's external environment (i.e. stimulus-dependent thoughts; SDTs), at times, the phenomenology of these two types of thought appears to be deceptively similar. But how similar are they? We address this question by comparing the content of two types of SIT (dreaming and waking SITs) with the content of SDTs. In this 7 day, smartphone-based experience-sampling procedure, participants were intermittently probed during the day and night to indicate whether their current thoughts were stimulus dependent or stimulus independent. They then responded to content-based items indexing the qualitative aspects of their experience (e.g. My thoughts were jumping from topic to topic). Results indicate substantial distinctiveness between these three types of thought: significant differences between at least two of the three mental states were found across every measured variable. Implications are discussed.

This article is part of the theme issue 'Offline perception: voluntary and spontaneous perceptual experiences without matching external stimulation'.

1. Introduction

During waking life, the contents of the mind are dynamically triggered by internal and external sources of stimulation. The immediate environment provides a constant source of perceptual input that can trigger *stimulus-dependent thoughts* (SDTs): thoughts, mental images and memories that are provoked by, or are a reflection of, the features of one's surroundings. At times, however, the content of the mind periodically strays away from any environmental demands or ongoing tasks and focuses on internally triggered thoughts that are decoupled from the external world [1]. Such *stimulus-independent thoughts* (SITs) roughly map onto the pervasive experience referred to as daydreaming or mind wandering (although see [2], for a discussion of complications in the definitions of these terms).

Multiple studies indicate a considerable degree of overlap between SITs and nocturnal dreaming. Indeed, cortical activation is comparable between these two states, particularly in memory-related regions of the brain and the default mode network [3]. Recent investigations also suggest that physiologically defined sleep can occur locally during wakefulness [4], which further calls into question the existence of a hard boundary between waking and dreaming. These local sleep episodes show experiential similarities to the attentional lapses that are characteristic of SITs. Although research comparing the experiential qualities of sleeping and waking SITs is limited, existing comparisons of first-person reports indicate notable similarities in core phenomenological qualities [5,6]. For instance, both states are characterized by similar emotional overtones, elements of fantasy and a lack of meta-awareness [3]. These findings have led researchers to suggest that 'waking and dreaming are not discrete states of consciousness with clearly defined parameters but rather represent continuous attentional states' ([7, p. 215]; see also [4]).

Notable distinctions between SITs and nocturnal dreaming do, however, exist. For instance, the mind is disengaged from the external environment during SITs, but it is not completely dissociated from it. Consequently, individuals typically have no trouble telling apart imagined images from actual perceptual imagery [4,5].[1] However, this is generally not the case in dreaming, as individuals tend to take their dream scenes to be real (i.e. they do not realize they are dreaming), suggesting differences in reality monitoring across these states [10].[2] Other evidence for a dissociation between dreaming and SITs comes from an intensive study examining the frequency of thinking. In this study, the prevalence of thought was compared across waking states, sleep onset, as well as non-rapid eye movement (NREM) and REM sleep; it was found that, upon waking, the period with the lowest frequency of reported thoughts was REM sleep [6], which suggests an important difference in the *quantity* of thinking during REM. Moreover, frequency of thinking during REM was found to covary negatively with hallucinations, suggesting important differences in the experiential quality of waking and sleeping states, particularly with respect to the prevalence of imagery.

Although research has found both differences and similarities between SITs and nocturnal dreaming, to date, no research has rigorously compared the core phenomenological features of these two SIT states with SDTs. This study aims to address this void in existing research by indexing and comparing the core phenomenological features across these three mental states—waking SITs, SDTs and dreams (nocturnal SITs)—using the Experience-Sampling Method (ESM). The ESM involves probing individuals to respond to questions periodically throughout several days. One of the main advantages of this method is that it allows for a more naturalistic approach to studying mental states as it captures ordinary experiences as they occur, with minimal temporal distance between the experience and the response [11]. By contrast, the vast majority of research on SITs and SDTs occurs under laboratory conditions, typically during which participants are asked to perform minimally demanding tasks [12,13]. Although a wealth of valuable information has been obtained from such research, it comes with the inevitable downside of lacking ecological validity.

Using the ESM, we sought to measure and compare key qualitative characteristics. We aimed to replicate past findings indicating that emotional valence and temporal focus differ between SDTs and SITs, while extending this research by also assessing and comparing characteristics of thoughts occurring during dreams. In addition, we assessed the following key characteristics, some of which have been studied in the context of mind wandering (e.g. [14]), but which have yet to be cross-compared across these three states: fluidity, spontaneity (versus intentionality), novelty, meaningfulness, bizarreness, goal-directedness and continuity (i.e. the degree to which thoughts jumped from topic to topic).

2. Methods

(a) Participants

The study was approved by the Institution Review Boards of Duke and University of California, Santa Barbara (UCSB). Participants were undergraduate students attending one of the two universities: 93 participants were recruited at UCSB and 47 at Duke, for a total of 140 participants (81 females); however, 131 completed the 7 day experience-sampling procedure. Respondents mean age was 19.3 years. They were invited to take part in the study in exchange for course credit(s) (for more details, see the Procedures section).

(b) Probe delivery

To capture the experiential quality of day-to-day thoughts in everyday contexts, we used a smartphone-based experience-sampling method that allowed participants to respond to triggers throughout their day. A number of mobile-based apps are now available to researchers conducting ESM-based research. In this study, MetricWire (https://metricwire.com/), a smartphone app designed specifically for research, was employed to trigger participants to respond to questions, as well as to present the questions and collect responses. MetricWire was chosen due to the functionality it provides, the ease of customizing responses and trigger times, and the ability to monitor participation while keeping responders' identities anonymous.

Triggers were delivered pseudo-randomly across three time blocks per day, such that two triggers randomly occurred between the following time periods: 9.00–13.00, 13.00–17.00 and 17.00–21.00. Two additional triggers occurred nightly at the fixed times of 3.00 and 5.30. These times were chosen to maximize the likelihood that participants would be awoken directly from the REM stage of the sleep cycle as past research indicates that the highest dream recall rates occur following REM awakenings (see [15]).

(c) Experiential dimensions

When triggered to respond to the survey, responders were first asked to indicate whether the thought they were just having was focused externally, on something in their environment (stimulus-dependent), or internally (stimulus-independent). Thought appraisals were then assessed across the following 10 dimensions: novelty, fluidity, meaningfulness, continuity, goal-directedness, bizarreness, spontaneity, emotionality, emotional valence and temporal orientation (see electronic supplementary material, table S1 for question format and corresponding response options). For temporal orientation, we included the following response options: past, present, future, none of these. The last option was included given that past research indicates that mind wandering can be atemporal (for a discussion of this topic, see [16]).

(d) Procedure

This study used a smartphone-based app (i.e. MetricWire) to enable experience sampling across a 7 day period. Participants received eight smartphone notifications per day, including two at night. Once notified, they were instructed that they should immediately respond to the surveys by opening the MetricWire app on their phones. Here, they would be asked to reflect on their conscious experience (within the 5 second window before being prompted) and judge whether they were having a thought that was internally or externally directed. A series of 10 questions followed, which aimed to capture the qualitative dimensions of their experience.

To ensure comprehension of the study requirements, participants came into the laboratory to receive an in-depth training procedure prior to the 7 day experience-sampling procedure. Instructions were explained in detail, both verbally and in written form, after which participants completed a comprehension check that tested them on basic information about the study (e.g. how many probes they would respond to per day). After each question, a subsequent screen appeared informing participants whether they were correct or incorrect in their given response, and the correct answer was reiterated. Participants then completed a practice trial of the probe items. This procedure ensured that every step of the study and each question item were correctly understood. Lastly, researchers had participants set two recurring alarms on their phones for 3.00 and 5.30. This was to ensure that participants would be awoken from sleep to answer the two nightly probes.

SONA credits were assigned based on the percentage of overall participation. All participants received a fixed one credit for attending the in-lab training session. If, after the 7 day period, participants completed 50–80% or greater than or equal to 80% of the surveys, they received an additional one or two credits, respectively.

(e) Coding of the variables

Eight of the 10 items (dependent variables) are binary and two are multi-categorical (refer to electronic supplementary material, table S1 for response options to each of the 10 questions). Of the eight binary variables, the following seven have Yes/No response options: meaningfulness, fluidity, topical shifts, goal-directedness, bizarreness and emotionality. For these items, Yes and No response options were coded as 1 and 0, respectively. The last binary variable measures spontaneity of the thoughts and has two response options: thoughts (i) were engaged deliberately, with intention, or (ii) came to mind spontaneously, out of nowhere. For this item, the latter response option was coded 1 (e.g. if thoughts were spontaneous) and the former response option was coded as 0 (e.g. if thoughts were deliberate). Therefore, in further analysis, this variable can be regarded as the proportion of responses for which the thought was classified as spontaneous (rather than deliberate).

The items assessing temporal orientation and emotional valence have multi-categorical response options. The response options for temporal orientation (past, present, future, none of these) were separated into four distinct variables. The resulting variable is binary for each subdimension; for example, the past variable is coded 1 if the thought was about the past and 0 for all other responses. A similar procedure was completed for emotional valence (positive, neutral, negative) such that three binary variables were produced.

Mental states were coded based on two criteria. For the daily probes, if participants responded that the thought was internally generated/directed, then it was classified as a stimulus-independent thought (SIT, henceforth). Alternatively, if the thought was externally triggered/directed, then it was classified as an SDT. Responses to nightly probes (i.e. occurring at 3.00 and 5.30) were classified as dreaming thoughts (note by definition, dreams cannot be stimulus-dependent). As described below, in order to obtain comparisons between these mental states all models were run twice, once with SITs as the reference group and again with SDTs as the reference group.

3. Results

Analyses of these data were intended to answer the question of whether differences exist in the phenomenological characteristics of waking SITs, SDTs and thoughts that occur while dreaming.

(a) Descriptive statistics

Descriptive statistics (mean, confidence interval, skewness and kurtosis) for each thought dimension were calculated and are presented in table 1. Given that all variables were binary, the means for each of the variables (except spontaneity) refer to the frequency of affirmative (Yes) responses and the 95% CI (i.e. 95% confidence interval) refers to the spread around each mean. For the spontaneity variable, the mean refers to the frequency of responses for which the spontaneous response option (compared to deliberate/intentional response option) was chosen. See figure 1 for a graphical representation of the frequency of occurrence for each thought dimension across the three mental states.

SDTs were the most commonly sampled mental state, followed by SITs, and then dreaming. Of all the probes, 53.6% were classified as SDTs (2372 samples), 29.3% were classified as SITs (1296 samples) and 17.2% were dreams (761 samples). Including only the daytime probes, 64.7% were SDTs and 35.3% were SITs. For daytime probes, across the whole sample, the average response rate was 66.2% (s.d. = 25.3), and for nightly probes, it was 41.2% (s.d. = 32.9). Overall, the average experience-sampling response rate was 59.9% (s.d. = 24.3). By participant, the average response rate for the daytime probes was $M = 27.9$, s.d. = 9.9 (66.4%; 42 total daytime probes over the 7 days) and for the night-time probes was $M = 5.9$, s.d. = 4.3 (42.1%; 14 total night-time probes over the 7 days). See electronic supplementary material, figures S4–S6 for further information on compliance and response rates. Note, 16 participants did not respond to any night probes and, consequently, could not contribute to analyses comparing daytime responses to night-time responses; however, their data were included in the analyses of daytime reports. Furthermore, there was a significant decrease in response rate across the 7 days for both day and night-time probes (see electronic supplementary material, S6).

(b) Multi-level binary logistic regression models

ESM data have a hierarchical structure; therefore, multi-level models were used to account for within-subject variation and missing data across participants. To test whether any of the thought dimensions differed between mental states (i.e. SITs, dreams and SDTs), separate multi-level binary logistic regression models were run.

Items with Yes/No responses were modelled in multi-level binary logistic regression models that examined the odds of participants responding 'Yes' (coded as 1) over the probability that they responded 'No' (coded as 0) to the questions assessing thought dimensions (e.g. 'My thoughts were novel'). Each binary item was entered as the dependent variable and mental states as the independent variable in separate models. Mental states were coded as 0 = SITs, 1 = dreaming and 2 = SDT, making SITs the reference group. In order to produce all three contrasts between the mental groups, the models were run a second time with SDT as the reference group (note, this analysis also produces one redundant contrast which is not further discussed). This procedure was repeated for the following variables that had Yes/No response options: novelty, fluidity, meaningfulness, topical shifts, goal-directedness, bizarreness and emotionality.

The output of the logistic regression is a conditional probability term indicating the likelihood that the outcome variable is equal to 1, or in this case 'Yes'. The results of these analyses are summarized in table 2 and are discussed in the following subsections. Note the intercepts for these analyses can be found in electronic supplementary material, S2.

Note that, given the multiple comparisons performed in this study, we discuss significance using a Bonferroni-

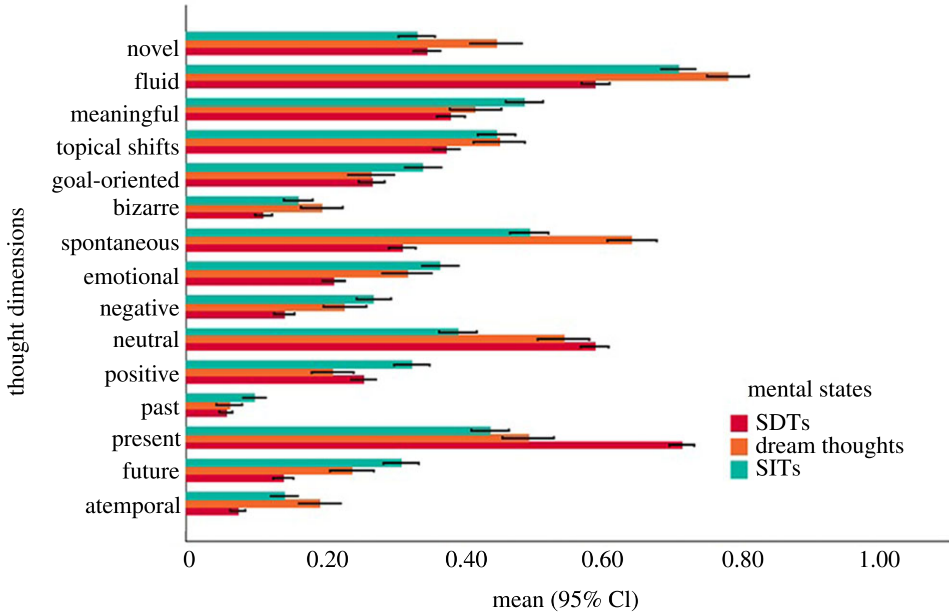

Figure 1. Graphical representation of the frequencies (in percentages) of occurrence of each thought dimension across the three mental states.

Table 1. Summary statistics for the thought dimensions across all mental states. CI, confidence interval; skew, skewness.

	SDTs			dreaming			SITs		
thought dimension	mean (%)	CI	skew/ kurtosis	mean (%)	CI	skew/ kurtosis	mean (%)	CI	skew/ kurtosis
novelty	35.2	[0.33–0.37]	0.62, −1.6	45.2	[0.41–0.49]	0.19, −2.0	33.7	[0.31–0.36]	0.69, −1.5
fluidity	59.6	[0.58–0.62]	−0.39, −1.9	78.9	[0.76–0.82]	−1.4, 0.008	71.6	[0.69–0.74]	−0.96, −1.1
meaningfulness	38.6	[0.37–0.41]	0.47, −1.8	42.1	[0.38–0.46]	0.32, −2.0	49.2	[0.46–0.52]	0.03, −2.0
topical shifts	37.9	[0.36–0.40]	0.50, −1.8	45.6	[0.42–0.49]	0.18, −2.0	45.2	[0.42–0.48]	0.19, −2.0
goal-directedness	27.1	[0.25–0.29]	1.0, −0.94	27	[0.24–0.30]	1.0, −0.92	34.5	[0.32–0.37]	0.61, −1.6
bizarreness	11.3	[0.10–0.13]	2.4, 4.0	19.8	[0.17–0.23]	1.5, 0.30	16.4	[0.14–0.18]	1.8, 1.3
spontaneity	31.6	[0.29–0.34]	0.79, −1.4	65.0	[0.62–0.68]	−0.63, −1.6	50.0	[0.47–0.52]	0.02, −2.003
emotional	21.6	[0.20–0.23]	1.4, −0.084	32.2	[0.29–0.36]	0.76, −1.4	37.0	[0.34–0.40]	0.54, −1.7
emotional valence: negative	14.4	[0.13–0.16]	2.0, 2.1	23.2	[0.20–0.26]	1.3, −0.38	27.3	[0.25–0.30]	1.0, −1.0
emotional valence: neutral	59.5	[0.57–0.61]	−039, −1.9	55.0	[0.51–0.59]	−020, −2.0	39.7	[0.37–0.42]	0.42, −1.8
emotional valence: positive	26	[0.24–0.28]	1.1, −0.80	21.4	[0.18–0.24]	1.4, −0.052	32.9	[0.30–0.36]	0.73, −1.5
past orientation	5.93	[0.05–0.07]	3.7, 12.0	6.4	[0.046–0.083]	3.6, 11.0	0.1	[0.08–0.12]	2.7, 5.1
present orientation	72.2	[0.70–0.74]	−0.99, −1.0	49.9	[0.46–0.54]	0.006, −2.0	44.3	[0.42–0.47]	0.23, −2.0
future orientation	14.2	[0.13–016]	2.0, 2.2	24.2	[0.21–0.27]	1.2, −0.54	31.3	[0.29–0.33]	0.81, −1.4
atemporal	7.7	[0.07–009]	3.2, 8.2	19.5	[0.17–0.23]	1.5, 0.37	14.4	[0.12–0.16]	2.0, 2.1

adjusted *p*-value. Fifteen phenomenological characteristics were measured in this study; thus, we use the adjusted *p*-value of $p = 0.003$ (i.e. 0.05/15).

(c) Novelty

As seen in table 2, the probability of responding 'Yes' to the question of novelty was greater for dreams compared with both SITs ($\beta = 0.63$, $p < 0.001$) and SDTs ($\beta = 0.41$, $p < 0.001$). The odds ratio for dreams compared with SITs and SDTs was 1.9 and 1.5, respectively. This term is the odds that novelty is present (i.e. novelty = 1) divided by the odds that it is not (i.e. novelty = 0) for reports of dreaming versus SITs, and dreaming versus SDTs. Converting odds to probability uses the following formula: odds/(1+odds). Using this formula, an odds value of 1.9 indicates that it is 66%

Table 2. Multiple multi-level binary logistic regression models for each dependent variable. IV, independent variable; s.e., standard error; CI, confidence interval; SDT, stimulus-dependent thought; SITs, stimulus-independent thoughts.

dependent variable	levels of IV	*β* (s.e.)	odds ratio [95% CI]
novelty	SDT (ref. SITs)	0.22** (0.09)	1.2 [1.1, 1.5]
	dreaming (ref. SITs)	0.63* (0.11)	1.9 [1.5, 2.3]
	dreaming (ref. SDT)	0.41* (0.10)	1.5 [1.2, 1.8]
fluidity	SDT (ref. SITs)	−0.63* (0.09)	0.53 [0.45, 0.63]
	dreaming (ref. SITs)	0.16 (0.12)	1.2 [0.94, 1.5]
	dreaming (ref. SDT)	0.79* (0.10)	2.2 [1.8, 2.7]
meaningfulness	SDT (ref. SITs)	−0.43* (0.08)	0.65 [0.56, 0.76]
	dreaming (ref. SITs)	−0.37* (0.10)	0.69 [0.56, 0.85]
	dreaming (ref. SDT)	0.056 (0.09)	1.1 [0.88, 1.3]
topical shifts	SDT (ref. SITs)	−0.39* (0.08)	0.68 [0.58, 0.79]
	dreaming (ref. SITs)	−0.074 (0.10)	0.93 [0.76, 1.1]
	dreaming (ref. SDT)	0.31* (0.09)	1.4 [1.1, 1.6]
goal-directedness	SDT (ref. SITs)	−0.35* (0.08)	0.70 [0.60, 0.83]
	dreaming (ref. SITs)	−0.43* (0.11)	0.65 [0.52, 0.81]
	dreaming (ref. SDT)	−0.077 (0.10)	0.93 [0.76, 1.1]
bizarreness	SDT (ref. SITs)	−0.22 (0.12)	0.80 [0.64, 1.0]
	dreaming (ref. SITs)	0.55* (0.14)	1.7 [1.3, 2.3]
	dreaming (ref. SDT)	0.77* (0.13)	2.2 [1.7, 2.8]
spontaneity	SDT (ref. SITs)	−0.75* (0.076)	0.48 [0.39, 0.58]
	dreaming (ref. SITs)	0.74* (0.10)	2.1 [1.8, 2.4]
	dreaming (ref. SDT)	1.48* (0.093)	0.23 [0.19, 0.27]
emotionality	SDT (ref. SITs)	−0.81* (0.09)	0.44 [0.38, 0.53]
	dreaming (ref. SITs)	−0.26** (0.11)	0.77 [0.63, 0.96]
	dreaming (ref. SDT)	0.55* (0.10)	1.7 [1.4, 2.1]

*$p < 0.003$; **significant at the standard p-value level ($p < 0.05$), but not at the Bonferroni-corrected level.

more probable that dreams are classified as novel compared with SITs, and 60% more likely that dreams are classified as novel compared with SDTs. The odds of responding 'Yes' to the novelty item was also significantly higher for SDTs compared to SITs. SDTs were not significantly more likely to be classified as novel compared to SITs at the Bonferroni-corrected level ($\beta = 22$, $p = 0.011$).

(d) Fluidity

The probability of responding 'Yes' to the question of fluidity (i.e. 'My thoughts were freely moving') was greater for dreams compared with SDTs ($\beta = 0.79$, $p < 0.001$) as well as SITs compared with SDTs ($\beta = 0.63$, $p < 0.001$). There was no significant difference in fluidity between dreams and SITs ($\beta = 0.16$, $p = 0.17$).

(e) Meaningfulness

The probability of responding 'Yes' to the question of meaningfulness (i.e. 'The content of my thoughts was important and meaningful to me') was greater in SITs when compared with both dreams ($\beta = -0.37$, $p < 0.001$) and SDTs ($\beta = -0.43$, $p < 0.001$). There was no significant difference in meaningfulness between dreams and SDTs ($\beta = 0.056$, $p = 0.56$).

(f) Topical shifts

The probability of responding 'Yes' to the question of topical shifts (i.e. 'My thoughts were jumping from topic to topic') was greater in SITs when compared with SDTs ($\beta = -0.39$, $p < 0.001$) and greater in dreams compared to SDTs ($\beta = 0.31$, $p = 0.001$). There was no significant difference in the experience of topical shifts between SITs and dreams ($\beta = -0.074$, $p = 0.47$).

(g) Goal-directedness

The probability of responding 'Yes' to the question of goal-directedness (i.e. 'My thoughts were focused on uncompleted personal goals') was greater in SITs when compared with both SDTs ($\beta = -0.35$, $p < 0.001$) and dreams ($\beta = -0.43$, $p < 0.001$). There was no significant difference in the goal-directedness of thoughts occurring in SDTs and dreaming ($\beta = -0.077$, $p = 0.46$).

(h) Bizarreness

The probability of responding 'Yes' to the question of bizarreness (i.e. 'My thoughts were bizarre and unusual') was numerically, though not significantly, greater in SITs when compared with SDTs ($\beta = -0.22$, $p = 0.056$). Dreams, as expected, were significantly more likely to be considered

Table 3. Multi-level binary logistic regression models for each dimension of temporal orientation. IV, independent variable; s.e., standard error; CI, confidence interval; SDT, stimulus-dependent thought; SITs, stimulus-independent thoughts.

dependent variable	levels of IV	β (s.e.)	odds ratio [95% CI]
past	SDT (ref. SITs)	−0.54* (0.13)	0.58 [0.45, 0.76]
	dreaming (ref. SITs)	−0.54** (0.18)	0.58 [0.41, 0.83]
	dreaming (ref. SDT)	−0.002 (0.18)	0.10 [0.70, 1.4]
present	SDT (ref. SITs)	1.1* (0.08)	3.1 [2.7, 3.6]
	dreaming (ref. SITs)	0.11 (0.10)	1.1 [0.91, 1.3]
	dreaming (ref. SDT)	−1.0* (0.11)	2.0 [1.6, 2.4]
future	SDT (ref. SITs)	−0.98* (0.09)	0.38 [0.33, 0.49]
	dreaming (ref. SITs)	−0.30** (0.11)	0.74 [0.59, 0.91]
	dreaming (ref. SDT)	0.68* (0.11)	2.0 [1.6, 2.4]
atemporal	SDT (ref. SITs)	−0.66* (0.13)	0.52 [0.41, 0.67]
	dreaming (ref. SITs)	0.68* (0.14)	2.0 [1.5, 2.6]
	dreaming (ref. SDT)	1.3* (0.14)	3.8 [2.9, 5.0]

*$p < 0.003$; **significance at the standard p-value level ($p < 0.05$), but not at the Bonferroni-corrected level.

bizarre compared with both SITs ($\beta = 0.55$, $p < 0.001$) and SDTs ($\beta = 0.77$, $p < 0.001$).

(i) Spontaneity

The probability of choosing the response option indicating the thought was spontaneous versus deliberate (i.e. 'My thoughts [were engaged deliberately, with intention/came to mind spontaneously, out of nowhere]') was greater in dreams when compared with SITs ($\beta = 0.74$, $p < 0.001$) and SDTs ($\beta = 1.48$, $p < 0.001$). Moreover, SITs were more likely to be considered spontaneous compared to SDTs ($\beta = -0.75$, $p < 0.001$).

(j) Emotionality

The probability of indicating the thought was emotional (i.e. 'My thoughts were emotional') was significantly greater in SITs when compared with both SDTs ($\beta = -0.81$, $p < 0.001$) and numerically, though not significantly, greater for dreams ($\beta = -0.26$, $p = 0.017$). Dreams were significantly more likely to be considered emotional than SDTs ($\beta = 0.55$, $p < 0.001$).

(k) Temporal orientation

Four separate models were run with the levels of temporal orientation (past, present, future and atemporal) serving as separate dependent variables. As seen in table 3, SITs were more likely to be about the past compared to SDTs ($\beta = -0.54$, $p < 0.001$) and dreams ($\beta = -0.54$, $p = 0.004$); note, however, that the latter comparison is not significant at the Bonferroni-correct level. There was no difference between SDTs and dreams ($\beta = 0.002$, $p = 0.99$). SDTs were more likely to be focused on the present compared to SITs ($\beta = 1.1$, $p < 0.001$) and dreams ($\beta = -1.0$, $p < 0.001$). There was no difference in the likelihood of present-focused thoughts between dreams and SITs ($\beta = 0.11$, $p = 0.26$). SITs were also more likely to be about the future than both SDTs ($\beta = -0.98$, $p < 0.001$) and dreams ($\beta = -0.30$, $p = 0.007$); however, dreams were also more likely to be about the future compared to SDTs ($\beta = 0.68$, $p < 0.001$). Thoughts could also be considered atemporal. Here, we found that SITs are classified as atemporal more than SDTs ($\beta = -0.66$, $p < 0.001$), but dreams are more frequently considered atemporal than both SITs ($\beta = 0.68$, $p < 0.001$) and SDTs ($\beta = 1.3$, $p < 0.001$).

(l) Emotional valence

Three separate models were run with the levels of emotional valence (positive, neutral, negative) serving as the separate dependent variables. As seen in table 4, SITs were more likely to be positively valenced than SDTs ($\beta = -0.26$, $p = 0.002$) and dreams ($\beta = -0.58$, $p < 0.001$). SDTs were more likely to be positive than dreams ($\beta = -0.32$, $p = 0.002$). However, SITs were also more likely to be negatively valenced compared with SDTs ($\beta = -0.80$ $p < 0.001$), and similarly dreams were more likely to be negatively valenced compared to SDTs ($\beta = 0.66$, $p < 0.001$). There was no significant difference in the likelihood of negative valence between SITs and dreams ($\beta = -0.14$, $p = 0.21$). SDTs were more likely to be considered emotionally neutral than SITs ($\beta = 0.75$, $p < 0.001$) but not dreams ($\beta = -0.19$, $p = 0.034$). However, dreams were more likely to be considered neutral than SITs ($\beta = 0.56$, $p < 0.001$). This suggests SITs tend to be more emotional (both in the negative and positive valence) than SDTs.

4. Discussion

SITs make up a large percentage of waking thoughts, but their defining features and the extent to which those features overlap with SDTs remain poorly understood. In this study, we compared the content of two types of SIT (dreams and waking SITs) with the content of SDTs. To our knowledge, this is the first attempt to cross-examine these three mental states across a broad range of phenomenological qualities. We aimed to explore the ways in which these three mental

Table 4. Multi-level binary logistic regression models for each dimension of emotional valence. IV, independent variable; s.e., standard error; CI, confidence interval; SDT, stimulus-dependent thought; SITs, stimulus-independent thoughts.

dependent variable	levels of IV	*β* (s.e.)	odds ratio [95% CI]
positive	SDT (ref. SITs)	−0.26* (0.08)	0.78 [0.66, 0.91]
	dreaming (ref. SITs)	−0.58* (0.11)	0.56 [0.45, 0.70]
	dreaming (ref. SDT)	−0.32* (0.11)	0.73 [0.59, 0.89]
neutral	SDT (ref. SITs)	0.75* (0.08)	2.1 [1.8, 2.5]
	dreaming (ref. SITs)	0.56* (0.10)	1.8 [1.4, 2.1]
	dreaming (ref. SDT)	−0.19** (0.09)	0.82 [0.69, 0.97]
negative	SDT (ref. SITs)	−0.80* (0.09)	0.45 [0.37, 0.54]
	dreaming (ref. SITs)	−0.14 (0.11)	0.87 [0.69, 1.1]
	dreaming (ref. SDT)	0.66* (0.11)	1.9 [1.6, 2.4]

*$p < 0.003$; **significance at the standard p-value level ($p < 0.05$), but not at the Bonferroni-corrected level.

states differ, and whether dreams and waking SITs show continuity in their experiential qualities. Results generally indicated distinct phenomenological characteristics among the three mental states. Significant differences between at least two of the three mental states were found in every measured variable. These findings speak to the richness of the experience-sampling approach in its ability to effectively capture distinct mental states as they occur in real-life contexts throughout the day (and night). Furthermore, SDTs and SITs significantly differed in their subjective qualities in a majority of cases, highlighting the importance of distinguishing between internal and external forms of attention in future research.

In addition to contributing to our understanding of the similarities and differences between SITs and SDTs, results of the present study shed some light on what has been referred to as the continuity hypothesis of waking and sleep mentation [3,4,7,17–23]. According to this hypothesis, the issues, concerns and goals that preoccupy spontaneous waking thoughts (e.g. SITs) continue into the dream state. Additionally, similar functions and underlying mechanisms are thought to be shared between these states [21]. Given that many aspects of SITs are thought to be shared with dreams, dreams are assumed to be more similar to SITs than SDTs.

Although the continuity hypothesis is straightforward, predictions about the expected degree of similarity in the phenomenology of these states is less clear. Whereas some suggest it is likely that there exist no sharp divisions between the phenomenology of waking SITs and dream mentation [24], others suggest that spontaneous waking thoughts (such as SITs) are phenomenologically distinct, but are an intermediary between sleep and goal-directed thoughts in their degree of cognitive control [21]. Certain phenomenal characteristics have indeed been shown to increase in intensity moving from goal-directed thought to spontaneous thought (typical of SITs) to dream mentation [3]. As such, it seems plausible that the phenomenology of SITs may be intermediate between dreams and SDTs. However, our results indicate a more complicated picture.

We found that overlap exists in the phenomenological quality of SITs and dreams for several of the characteristics. For instance, waking SITs and dreams did not differ in their likelihood of being classified as temporally present-focused (note, both had a lower likelihood than SDTs), negatively valenced, fluid, nor did they differ in the extent to which they comprise topical shifts. For these dimensions, there is an indication that the phenomenology of dreams and waking SITs are similar, although not necessarily continuous (i.e. ranging in degree). However, in some cases, we found a continuously increasing likelihood of experiencing certain phenomenological characteristics as we moved from dreams to waking SITs to SDTs. This was the case for spontaneity and atemporality (thoughts classified as atemporal rather than past, present or future focused). There was a significantly greater likelihood of dreams being classified as spontaneous and atemporal when compared with SITs, while SITs were also significantly more likely to be classified as such compared with SDTs.

The other measured characteristics, however, showed a dissimilar pattern, which does not appear to support a continuity hypothesis. At times dreams differed from both SITs and SDTs, as in the case for bizarreness; dreams were more likely to be bizarre than both SDTs and SITs, and the latter two did not differ in likelihood. At other times, dreams were intermediary between SITs and SDTs, such as in the case of meaningfulness; SITs were most commonly classified as meaningful, followed by dreams, and then SDTs. At other times, no differences were found between SDTs and dreams, as in the case of goal-directedness, when SITs were more likely to be identified as more goal-directed than both dreams and SDTs. Therefore, when mind wandering is defined as SIT, we find mixed support for a continuum hypothesis suggesting that the phenomenology of SITs is intermediate between dream mentation and SDTs.

Turning our focus to each thought dimension, we found an interesting pattern of results. In terms of temporal orientation, SDTs were more likely to be about the present moment than both dreams and SITs, as is to be expected as these thoughts are generally assumed to be directed at the here and now. Consistent with past research, both SITs and dreams were more likely to be about the future compared to SDTs [25]. This aligns with past views that SITs and dreams may play a role in anticipating and planning the future [12,26–29]. However, SITs were also more likely to be about the past when compared with SDTs. One possibility is that thinking of the past (which permits people to imagine what could have been done differently) allows individuals to prepare and respond more effectively to similar future events.

This is supported by research indicating that mind wandering recruits memory-related regions [3] and that memories serve to simulate, and make predictions about, the future [30,31]. Dreams were also most likely to be considered atemporal compared to both SITs and SDTs, perhaps indicating an interesting distinction in the phenomenology of dream versus waking mentation.

Our results support past theories suggesting that a key function of waking thoughts may be to solve problems in order to meet future goals [27,32]. Indeed, we found that SITs were more likely to be goal-oriented when compared with both SDTs and dreams. One important reason for thinking about the future may be to simulate situations that make it more likely that one will reach one's future goals [33]. This may also explain why, on average, SITs were rated as being significantly more meaningful than both SDTs and dreams.

SITs were less likely to be considered novel than dreams, perhaps indicating the presence of repetitive thought content. Given the temporal orientation of these thoughts, such content may include memories or the attainment of future goals. Dreams tended to be the most novel and bizarre, indicating that while both dreams and SITs may function to simulate the future, they may do so in different ways. Dreams allow less-constrained simulations by deactivating brain areas responsible for limiting thoughts to the logical, familiar, or relevant and priming associative networks [34]. Thus, simulations of possible future concerns or goals contain more original, even bizarre, elements and increase the possibility of novel associations [35]. Put differently, 'dreams are simply thought in a different biochemical state' [36, p. 91]: a state that provides a novel orientation towards the same ideas, concerns or goals that make up waking thought. This is supported by research indicating that REM sleep can promote problem-solving and creative insight [37].

(a) Limitations and future directions

We should be very cautious generalizing the present findings to other forms of mind wandering, such as task-unrelated thoughts (TUTs), given that, in this study, mind wandering was defined only by stimulus-independence. Some evidence suggests that differences in phenomenological characteristics may exist between types of mind wandering (e.g. between future-oriented versus non-future-oriented mind wandering; [38]). Therefore, other types of mind wandering (e.g. TUT or unintentional thought) should be examined in future research, while including a broad range of phenomenal characteristics, to determine whether support for the continuum model would appear when measuring other varieties of mind wandering.

In this study, dreams were categorized as SDTs, given that the definition of stimulus dependence precludes dreams. Nevertheless, individuals may have the sense that some of the thoughts that occur during dreams are stimulus dependent, given that the dream is generally mistaken as a real, objective reality by the dreamer [39]. Future research should, therefore, explore this possibility and determine whether thoughts classified by dreamers as stimulus dependent share some of the phenomenological characteristics of waking SDTs.

This study differs from many previous studies in that the measures were taken during everyday life, rather than when performing minimally demanding tasks, as in the more commonly used laboratory-based paradigms. Although this is a more ecologically valid method of measuring mental states, the current study sample consisted wholly of undergraduate university students. Given that past research has found differences in certain qualities of mind wandering as a function of demographic factors, such as age (e.g. [40]), this research should be replicated using more heterogeneous populations.

Also noteworthy is that, as in previous work using ESM (e.g. [40]), there existed a considerable decline in the number of responses across participants over the course of the 7 day sampling procedure, as well as a wide range of variability in response rates between participants (see electronic supplementary material, figures S4 and S5). It is possible that a systematic relationship exists between the qualitative aspects of thinking and the propensity to respond to the probes. This may be especially true for the night probes; for instance, participants who have interesting or bizarre dreams may be more motivated to report them. Indeed, past research indicates that dream report frequency correlates to interest in dreams [41].

With respect to future directions, future research on the topic would seemingly benefit from the inclusion of individual-difference measures. Indeed, past work indicates that individual differences in the connectivity of the default mode network—which is active during mind wandering—may be related to differences in occurrence and qualitative aspects of an individual's spontaneous thoughts [13,42,43]. Furthermore, there may exist a relationship between certain personality characteristics and compliance in responding to probes or response style; for instance, intolerance to ambiguity has been found to predict extreme responding, or the tendency to over-use the endpoints of a Likert scale [44]. Although our probes used dichotomous response options, the style or rate of responding may be affected by these variables. Future research should examine these possibilities.

Finally, in our study, we did not include additional measures to determine the impact that responding had on participants. It is possible, however, that waking up to respond to the night-time probes significantly affected sleep quality or the phenomenological qualities of dreams or waking thoughts. Given that previous work has found a link between sleep disturbance and mind wandering [45], it will be important for future iterations of this study to examine and, if possible, protect against, this possibility.

(b) Concluding remarks

This study used an in-depth, 7 day experience-sampling procedure to explore differences in the phenomenological characteristics of different types of thought. Our findings suggest mixed support for a continuum model of dream mentation and waking thoughts. We have robust evidence, however, supporting distinct phenomenological characteristics between SDTs versus SITs. For this reason, it is important for future work on the topic of mind wandering to separately examine these two types of thought. The current study opens up many possible future directions to further explore the content, context and phenomenology of various types of thought.

Data accessibility. Data for this study and syntax used to analyse the data are publicly available at the following osf registry: https://osf.io/zjtrk/.

Authors' contributions. M.E.G. and A.P.S. carried out the experiment. M.E.G. conducted the analyses with advice from Y.M.G. M.E.G. wrote the manuscript and created the tables/figures with feedback and/or edits from all authors. P.S. and J.W.S. helped supervise the project. P.S. conceived of the original idea, which was further developed and planned by all authors.

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Endnotes

[1]Note, however, that some exceptions do exist; for instance, difficulties in reality monitoring, as in the case of psychosis, and the perky effect (see [8,9]).

[2]Here, too, some exceptions exist, as in the case of lucid dreaming, which is a state during which dreamers are aware that they are dreaming [10].

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