Title

Dreams reflect nocturnal cognitive processes: Early-night dreams are more continuous with waking life, and late-night dreams are more emotional and hyperassociative

Running title: Dreams reflect nocturnal cognitive processes

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Abstract

Contributions of specific sleep stages to cognitive processes are increasingly understood. Non-REM sleep is particularly implicated in episodic memory consolidation, whilst REM sleep preferentially consolidates and regulates emotional information, and gives rise to creativity and insight. Dream content reflects these processes: non-REM dreams are more likely to picture episodic memories, whereas REM dreams are more emotional and bizarre. However, across-the-night differences in the memory sources of dream content, as opposed to sleep stage differences, are less well understood. In the present study, 68 participants were awoken from sleep in the early and late night and recorded their dreams and waking-life activities. Early-night dreams were more clearly relatable to (or continuous with) waking life than late-night dreams. Late-night dreams were more emotional-important, more time orientation varied, and more hyperassociative, than early-night dreams. These dream content differences may underlie the mental content that accompanies sleep processes like memory consolidation, emotion-processing, and creativity.

Keywords: dreaming, REM and non-REM sleep, the Continuity Hypothesis, metaphor, hyperassociativity

1.1 Introduction

Sleep is crucial for various cognitive functions, including memory consolidation and transformation (e.g. Stickgold, 2005), processing and attenuating the intensity of emotional memories (e.g. Vandekerckhove & Cluydts, 2010; Walker & van der Helm, 2009), and thinking creatively about previously-acquired information (e.g. Stickgold & Walker, 2004). Different stages of sleep contribute differentially to each process. For example, rapid-eye-movement (REM) sleep, the stage of sleep electrophysiologically most similar to wakefulness and characterised by its eponymous rapid saccadic movements of the eyes, preferentially consolidates emotional memories (Sopp et al., 2017) and is the stage of sleep responsible for down-regulating the emotional intensity associated with emotional memory recall (Rosales-Lagarde et al., 2012). An emerging body of evidence is also beginning to find that it is REM sleep specifically that contributes to creative, associative, fluid types of thinking in wakefulness (Cai et al., 2009; Carr & Nielsen, 2015; Walker et al., 2002). The other three stages of sleep, collectively known as non-rapid-eye-movement (non-REM) sleep, conversely, are crucial for the strengthening of episodic memories relevant to one's future and past (Born & Wilhelm, 2012). Non-REM includes slow wave sleep (SWS), which involves electrophysiological features such as eponymous slow oscillations (waves), sharp-wave ripples, and spindles, and is specifically implicated in the reactivation of memories at a neural level (Ribeiro et al., 2004). Although these relative benefits of REM and non-REM sleep are now well-delineated, it is likely that the two operating sequentially across the night are needed for a fully functioning cognitive system comprising, amongst other functions, memory consolidation, emotion-regulation, and creative thinking (e.g. Cairney, Durrant, Power & Lewis, 2015; Fogel et al., 2009; Giuditta et al., 1995).

Dreaming is the subjective conscious mental experiences one has during sleep. If dreams offer an experiential window into sleep (the "transparency assumption": Windt, 2013), then dream content should clearly mirror stage-of-sleep differences in sleep-dependent cognitive processes. Indeed, this has been found across many research studies. For example, non-REM dreams tend to be more related to episodic memories (Baylor & Cavallero, 2001), and to current waking life (Battaglia et al., 1987; Hobson, Pace-Schott, & Stickgold, 2000), than REM dreams, reflecting the non-REM sleep process of reactivating recent memory traces in order to strengthen their recallability for future retrieval. REM dreams, conversely, tend to be more emotional and more bizarre (Hobson, Pace-Schott, & Stickgold, 2000; Smith et al., 2004), reflecting the role of REM sleep in processing emotions and thinking fluidly and creatively. REM sleep dreams are also the only ones to exhibit the "dream-lag" effect (the tendency for waking-life experiences to appear in dreams on the first and then the fifth-to-seventh night after the experience); and on the experience's second appearance in dreams, becomes more abstracted, again likely reflecting the associative/abstracting cognition more inherent to REM sleep (Blagrove et al., 2011; van Rijn et al., 2015).

However, differences between REM and non-REM dreams become less clear-cut towards the end of a night's sleep: 10-30% of late-night non-REM dreams are indistinguishable from REM dreams (Antrobus et al., 1995; Monroe et al., 1965). While it is as yet unclear why REM and non-REM dreams become more similar as the night progresses, it may be due to the brain activity changes that occur across the night that are currently unmeasurable by standard polysomnography. For example, there may be more "covert REM" (Nielsen, 2000) during non-REM sleep in the late than the early night, such as more PGO-wave activity (Carhart-Harris, 2007; Gott et al., 2017), which would account for the enhanced "dream-likeness" of non-REM dreams later in the night. Broadly speaking, SWS occurs more in the first half of a typical night of sleep, and REM occurs more in the second half. Indeed early studies exploring sleep and memory consolidation often involved depriving participants of either the first or second half of sleep, as a way of indirectly manipulating sleep stages (e.g. Yaroush et al., 1971).

Because dream content varies both as a function of stage of sleep *and* time spent asleep, it is important to have data on both in order to be able to understand how sleep processes change overnight. For example, hallucinatory thoughts are more frequent in REM than non-REM dreams across the night, but directed thought is only more frequent in non-REM dreams in the first 5 hours of the night (Fosse, Stickgold, & Hobson, 2004). Similarly, only REM dreams become more emotionally intense, bright, and clear later in the night, but both REM and non-REM dreams become more bizarre, dreamlike, and longer (Wamsley et al., 2007). Conversely, Fosse et al. (2001) found no differences in emotional intensity between early- and late-night REM dreams for the seven emotions investigated other than surprise.

Malinowski and Horton (2014) investigated various dream dimensions (e.g. wake-dream continuity, emotionality, and metaphoricity) across the night. Overall time of night was found to have a large effect on the dream dimensions measured, however, due to the small sample size it was not possible to detect effects on individual dimensions. Some patterns were discernible, however, such as overall decreases across the night of wake-dream continuity, overall increases of metaphoricity and bizarreness, and larger correlations between wake-dream continuity variables in late-night than early-night dreams, indicating that effects may be detectable with a sufficiently powered dataset. When taken in conjunction with Fosse et al.'s (2004) and Wamsley et al.'s findings, it appears that "dream-like" cognition increases as a function of time spent asleep over and above sleep stage, reflecting the change towards fluid, creative, and hyperassociative cognitive processes that underlie sleep towards the latter part of the night.

The idea that dreams can be "hyperconnective" or "hyperassociative" has existed for decades (e.g. Breger, 1967; Hartmann, 1996), and "hyperassociative" is a term that is oft-used to describe the nature of some dreams (e.g. Llewellyn, 2013; Stickgold et al., 2001). However, this term often lacks a clear operational definition, making it difficult to measure. Hartmann (1996) conceptualised dreaming cognition as being in opposition to focused, goal-directed waking cognition. He claimed that the latter operates in a feed-forward, relatively linear fashion in order for us to be able to process sensory inputs from the external world and produce appropriate outputs. The former, conversely – operating free from the constraint of having to interact with the external world – is able to make broader, non-linear connections.

These broad, non-linear connections that may be made in dreaming cognition, or "hyperassociativity", can be conceptualised in a number of ways, including the following: the appearance of disparate and fragmented waking-life memory sources in a dream; dream "bizarreness"; wide time orientation variance within a dream; and the metaphoricity of a dream, i.e. its non-literal associations with waking life (Horton & Malinowski, 2015; Malinowski & Horton, 2015). We will focus on bizarreness, time orientation variance, and metaphoricity for the purposes of the present research, each of which will be briefly defined next.

Hyperassociativity may underlie some types of dream "bizarreness", since the bizarreness of some dreams may come from their binding together of disparate, unconnected memories (Levin and Nielsen, 2009; Payne, 2010; Revonsuo and Tarkko, 2002, Stickgold et al., 2001). Because of their intense (hyper)connectivity, dream scenes may seem bizarre to the waking mind, as they may bring together memories, thoughts, and experiences from seemingly unrelated components of the dreamer's life – such as concurrently picturing characters from a television series, people and places from childhood, current anxieties about a relationship or work, and events anticipated for the future (Horton & Malinowski, 2015). Dream bizarreness has been attempted to be measured in some research using content analysis (e.g. Revonsuo & Salmivalli, 1995), but external raters underestimate the amount of bizarreness in a dream in comparison to dreamers' own ratings (Schredl & Erlacher,

2003). As such, self-rating for dream bizarreness is the most appropriate method for measuring this aspect of dream hyperassociativity.

Dreams may also be hyperassociative via wide time orientation variance. This refers to dreams in which memory sources from multiple time periods of the dreamer's life are activated in one dream (such as from their past, present, and anticipated future). Cartwright, Lloyd, Knight, and Trenholme (1984) found that dreams of non-depressed divorcees had more of this "variance in time orientation" (p.255) than did dreams of depressed divorcees, perhaps tentatively indicating an adaptive role for hyperassociativity in terms of emotion regulation and coping with life crises. Another way to measure hyperassociativity, then, is to measure the amount of time orientation variance within a dream: the extent to which it refers simultaneously to multiple time orientations in the dreamer's life. As with bizarreness, at least some of this variation in time orientation relies upon a single dream comprising multiple memory sources.

Another way to conceptualise hyperassociativity is in terms of a dream's metaphorical relationship with its waking-life referents, or its metaphoricity. While some dreams picture waking-life thoughts or experiences directly and literally (such as dreaming about failing an exam when worried about an upcoming exam), other dreams have a more distant and sometimes metaphorical relationship to their waking-life source (such as dreaming about failing an exam during a time of unrelated stress, perhaps many years after last taking an exam). In metaphorical wake-dream relationships, the dream's association to its waking-life source is much more distant, perhaps bridged only by an emotion, or by stress. This was illustrated clearly by Davidson and Lynch (2011), in which participants who watched a video of 9/11 experienced more literally related dreamt content (e.g. "George Bush"), closely related dreamt content (e.g. "president(s)"), *and* distantly related dream content (e.g. "leader(s) or government official(s)") than a control group. A literal dream depiction of a waking-life memory source could be described as closely associative, whereas a distantly related image could be described as hyperassociative or possibly metaphorical.

Domhoff's (1993) discussion of the dreams of Vietnam veterans gives an illustration of how metaphor and hyperassociativity are related concepts. Decades after their return from the war, the veterans began dreaming of it again during times of unrelated stress. The present day issue, which was totally unrelated to the Vietnam war, appears to have opened up a hyperassociative pathway back to the war, bridged by stress. In this way it is hyperassociative, but it is also metaphorical, using the definition of metaphor as "mapping features that appear within one domain to an object from a different domain", and noting that "tenor and vehicle need not share any features" (Tourangeua and Rips, 1991, p.453). The present day issue is the tenor and the Vietnam war is the vehicle.

It may be the hyperassociative way in which waking-life experiences give rise to dream content, then, that also gives rise to dream metaphor – at least in some cases. In addition, Malinowski and Horton (2014) found that self-reported metaphor and bizarreness are very highly correlated, perhaps evidencing a relationship between dream metaphoricity and dream hyperassociativity, if the latter indeed underlies some types of dream bizarreness. Thus, another potential measure of dream hyperassociativity is dream metaphoricity. Whilst one may assume that hyperassociativity and metaphorical representation (in addition to bizarreness, which has already been evidenced (Hobson, Pace-Schott, & Stickgold, 2000) feature more greatly in REM than non-REM sleep, we may also expect to see an increase in the extent of hyperassociativity, metaphoricity and bizarreness in dreams sampled from across the night, i.e. as a function of time spent asleep.

The activation of memories during sleep, which appear in recalled dream reports, likely reflects memory activation underlying sleep-dependent memory consolidation (e.g. Horton & Malinowski, 2015; Wamsley & Stickgold, 2018; Wamsley, Tucker, Payne, Benevides & Stickgold, 2010; Schredl,

2017). Changes in dream content and characteristics over the course of the night can provide insights into the nature of these processes of memory activation. Whilst evidence that dream components change across the night has existed for decades (e.g. Kramer, 1964; Verdone, 1967), we formulated three hypotheses to test the theory that dream content varies as a function of time spent asleep, more specifically.

The present study, then, aimed to measure differences in dreams according to the amount of time spent asleep, replicating Malinowski and Horton (2014) with a larger sample size and a revised conceptualisation and measurement of hyperassociativity. Three hypotheses were made, as follows. First, based on the evidence that non-REM sleep (which dominates early-night sleep) contributes to the consolidation of recent waking-life memories, it was hypothesised that dreams would be more clearly continuous with waking-life experiences in early- than late-night dreams. Second, based on the evidence that REM sleep (which dominates late-night sleep) contributes to the consolidation and processing of emotional experiences, it was hypothesised that late-night dreams would be more emotionally intense than early-night dreams. Finally, based on the evidence that REM sleep contributes to fluid, creative, and associative cognitions, it was hypothesised that late-night dreams would exhibit more hyperassociativity, such as in term of bizarreness, time orientation variance, and metaphoricity than early-night dreams. Furthermore, we aimed to explore the nature of hyperassociativity within dreams, using evidence-based and clearly delineated measures, empirically for the first time.

2.1 Materials and Methods

2.1.1 Participants

Based on the medium-to-large effect size ($\eta p^2 = .51$) between early and late dreams reported in Malinowski & Horton (2014), an *a priori* power analysis for repeated-measures t-test was conducted with G*Power 3 (Faul, Erdfelder, Lang, & Buchner, 2007) to predict the sample size required. It was estimated that approximately 66 participants would be required with an alpha level of .01 and power of .80.

Participants (N=68) were students at the University of Bedfordshire and Leeds Beckett University. Eight were male, 58 were female, and two participants did not provide information about their sex. Ages ranged between 18 and 52, with a mean of 25.49 (SD=8.60). Recruitment was conducted via posters and announcements at the universities. Participants received £20 in thanks for their time and participation. Participants were only permitted to take part if they self-reported that they: were 18 years of age or over; were in good general health; did not suffer nor had ever suffered from any sleep disorders or any health problems that may affect sleep (e.g. depression); did not suffer from any health problems that might worsen as a result of being awoken several times during the course of a night's sleep; slept at least 6 hours a night; and were not taking medication that may affect their sleep, such as anti-depressants. Participants were also asked to sleep alone for the duration of the study.

2.1.2 Design

Participants completed a structured diary of waking experiences and associated rating scales for two non-consecutive days (Days 1 and 3) and were systematically awakened at four pre-programmed points throughout the subsequent night (Nights 1 and 3) to report any mental content experienced

before they were woken. The mental content (dreams) were audio-recorded and re-played upon full awakening the morning following (Days 2 and 4), at which point a Dream Questions Form was completed. Participants were given a rest night (Night 2) in between the two dream-recording nights. See Figure 1.

The characteristics of the waking experiences are not reported here. Rather, the present paper focuses upon the characteristics of the dreams that emerged across the four nightly awakenings: 2 hours ("early"), 4 hours ("early-mid"), 6 hours ("mid-late") and 8 hours ("late") after self-reported typical bedtime.

Continuity across the night was assessed by exploring the characteristics of dreams via the Dream Questions Form as a function of time of awakening.

2.1.3 Materials

A Sony XDRC706DBP DAB+/DAB Digital Clock Radio was used to awaken participants from their sleep each night of the experiment. Clocks were pre-programmed with four alarms (two, four, six, and eight hours after bedtime).

An Olympus VN-7700 Digital Voice Recorder was used to record dreams following awakenings.

The Waking-Life Experiences Form (one each for Nights 1 and 3). This form instructed participants to record between 10 and 20 waking-life experiences and/or thoughts from their day that day. They were instructed to record most of what they experienced that day in the form. Examples were given for experiences: eating, studying, working, travelling from one place to another, hobbies, reading, watching TV or films, interacting with other people, thinking about something, or anything else. Participants were instructed to think chronologically through their day and try to provide a reasonably comprehensive account of what they did and what they experienced. In addition to recording these experiences, participants were asked to rate each one for five different dimensions: 1) how emotionally intense it was (0=not at all emotionally intense, 9=as emotionally intense as it's possible to be); 2) how negative or positive it was (-3= as negative as it's possible to be, +3= as positive as it's possible to be, 0=neither negative nor positive); 3) how stressful it was, whereby 'stress' is a specifically negative experience and may include physiological responses such as raised heart rate (0=not at all stressful, 9=as stressful as it's possible to be); 4) how important this experience was to them personally (0=not at all important, 9=as important as it's possible to be); and 5) future use, that is, how likely they thought they were to experience this again in the future, (0=definitely not going to experience this again, 9=extremely likely to experience this again). Space was provided for up to 20 waking-life experiences/thoughts and their associated five dimensions. Results from the five dimensions are not reported in the present paper.

The Waking-Life Experiences in Dreams Form (one for each morning following Nights 1 and 3). This form instructed participants to consult the list of 10-20 waking-life experiences they recorded the evening before. If they dreamt of any of the experiences that they recorded, participants were asked to put an "X" next to the corresponding number on this form, and state which awakening it came from (1^{st}, 2^{nd}, 3^{rd}, or 4^{th} awakening). Space was provided for up to 20 waking-life experiences in dreams.

The Dream Questions Form (one each for each awakening for Nights 1 and 3). This form instructed participants to think about each dream they recorded and about how it related to their waking life *overall* (not just the previous day). Participants were instructed to bear in mind that dreams may be

literally related to waking life, such as dreaming that they went to the wrong exam during your exam revision time, but that at other times dreams may be related to your waking life in less literal ways, such as dreaming of *being* lost when *feeling* lost in waking life, or dreaming about their studies in a strange way that is not at all like waking life. Participants were asked to answer 13 questions about each dream, thinking about how related it was to their waking life, regardless of whether the relationship was literal or not:

1. How related is the dream to your *present* (within the last month) waking life on a scale of 0-9, where 0 = no part of the dream is related to your present waking life, and 9 = every part of the dream is related to your present waking life?

2. How related is the dream to your *recent past* (between a month and a year) waking life on a scale of 0-9, where 0 = no part of the dream is related to your recent past waking life, and 9 = every part of the dream is related to your recent past waking life?

3. How related is the dream to your *distant past* (over a year ago, including childhood) waking life on a scale of 0-9, where 0 = no part of the dream is related to your distant past waking life, and 9 = every part of the dream is related to your distant past waking life?

4. How related is the dream to your *future* waking life (i.e., things you are anticipating for the future) on a scale of 0-9, where 0 = no part of the dream is related to your future waking life, and 9 = every part of the dream is related to your future waking life?

5. How related is the dream to your waking life *in general* (present, past, or future) on a scale of 0-9, where 0 = no part of the dream is related to waking life, and 9 = every part of the dream is related to waking life?

For the next two questions, participants were asked about whether the dream was *literally* related to waking life or *not literally* related to waking life. They were instructed that if the dream was literally related, it could be said to be *similar* to their waking life; or, if it was not literally related, it could be said to be *metaphorical* for their waking life.

6. How *similar* is the dream to your waking life *in general* (present, past, or future) on a scale of 0-9, where 0 = no part of the dream is similar to your waking life, and 9 = every part of the dream is similar to your present waking life?

7. How *metaphorical* is the dream to your waking life *in general* (present, past, or future), on a scale of 0-9, where 0 = no part of the dream is metaphorical for waking life, and 9 = every part of the dream is metaphorical for waking life?

This question, in part, explored hyperassociativity.

For the next question, participants were instructed that they may find emotions in their dream relating to emotions in waking life: for example, if they were feeling guilty about something, they might feel guilty in their dream; or if they felt anxious about something in waking life, they might feel anxious in their dream, and so on. For this question, participants were told that it does not matter if the dream was similar to waking life or a metaphor for waking life, but to focus only on its emotional content and how similar that was to their emotions in waking life.

8. How *emotionally continuous* is the dream with your waking life *in general* (present, past, or future), on a scale of 0-9, where 0 = no part of the dream is emotionally continuous with waking life, and 9 = every part of the dream is emotionally continuous with waking life?

Finally, participants were asked the following questions:

9. How bizarre is the dream on a scale of 0-9, where 0 = there are no bizarre elements at all to the dream, and 9 = dream is as bizarre as it can be?

10. How emotionally intense was your dream on a scale of 0-9, where 0 = not at all emotional, and 9 = as emotional as it is possible to be?

This question directly assessed the prediction concerning emotional intensity of dreams increasing across the night.

11. How negative or positive was the dream on a scale of -3 to +3, where -3 = as negative as it's possible to be, 0=neutral, and +3 = as positive as it's possible to be)?

12. How stressful was your dream scale on a scale of 0-9, where 0 = not at all stressful, and 9 = as stressful as it is possible to be?

13. How important would you say your dream was to you on a scale of 0-9, where 0 = not at all important, and 9 = as important as it is possible to be?

2.1.4 Procedure

Individuals who responded to advertisements for the experiment were provided with a participant information sheet which detailed what they would be asked to do if they chose to participate. Those individuals who agreed to participate provided their usual bedtime, then met with a member of the research team (either one of the researchers or a student research assistant) to sign the consent form and receive the instructions and materials for their participation. During this meeting, participants received an alarm clock which the researchers pre-programmed to sound at four intervals throughout the night: two hours, four hours, six hours, and eight hours after the participants' usual bedtime. It was emphasised to participants that they should stick to their usual bedtime within 30 minutes either side. For example, if the specified bedtime was 23:00, participants were advised to ensure they were in bed between 22:30 and 23:30. Participants were advised to keep the alarm clock on during the first night of the experiment, turn it off for the second (second night without alarms to allow participants to recover from first night of interrupted sleep), and back on for the third night. In addition to the alarm clock, participants were given hard copies of several forms: two Waking-Life Experiences forms (one for Night 1 and one for Night 3); two Waking-Life Experiences in Dreams Forms (one for morning after Night 1 and one for morning after Night 3); and eight Dream Questions forms (one for each awakening: four in Night 1, and four in Night 3). Participants also received a Dictaphone and were given instructions on its operation.

Participants were given standardised instructions both verbally during their initial meeting with one of the researchers, and a hard copy, for the entire experiment, as follows:

1. Check that you have the Dictaphone, alarm clock, and all the forms you need.
2. Before bed on night one of the experiment, fill in the "Waking-Life Experiences" form.
3. Go to bed at your normal hour with the alarm clock and Dictaphone nearby.

4. When you are awoken by the alarm clock, turn on the Dictaphone and verbalise any dreams or anything you can remember from what was going through your mind when you were asleep, in as much detail as you can remember. This process will be repeated four times in the night.
5. When you have been awoken for the last time, go back to sleep and rise from bed as per normal.
6. In the morning, you will find your recorded dreams on the Dictaphone. Listening to these for reference, fill in the "Waking Life Experiences in Dreams" form and the "Dream Questions" form.
7. On the second night of the experiment, sleep as per normal, without the alarm clock.
8. On the third night of the experiment, repeat instructions 1-6.
9. At the end of the experiment i.e. the morning after the third night, return the equipment and forms to the experimenter and receive your £20 'thank you' for you participation.

Following participation, participants met a second time with one of the researchers and received a debriefing and a £20 voucher in thanks for their participation.

The study abided by the British Psychological Society's ethical guidelines and received ethical approval from institutional ethics committees at the University of Bedfordshire and Leeds Beckett University.

3.1 Results

The average dream recall rate across all 8 awakenings (2 experimental nights x 4 awakenings) was 71%. Dream recall was as follows for each awakening: 59% (81 dreams) from the early awakenings (65% (44 dreams) on night 1, 54% (37 dreams) on night 3); 68% (92 dreams) from the early-mid (78% (53 dreams) on night 1, 57% (39) on night 3); 59% (80 dreams) from the mid-late awakening (59% (40 dreams) on night 1, 59% (40 dreams) on night 3); and 71% (97 dreams) from the late-night awakenings (78% (53 dreams) on night 1, 65% (44 dreams) on night 3). The difference in dream recall across the four awakenings, and also across the two nights, was non-significant. Whilst dream report lengths were not calculated in terms of word counts, a sample of dream recordings were comparable in length (seconds) across the awakening periods.

3.1.1 Effects of time spent asleep on dream variables

The first aim of the study was to explore wake-dream continuity across the night. Table 1 shows the descriptive trends for the 13 Dream Questions Form variables, at each time-point.

To test the effect of time spent asleep on the dream variables, firstly a Principal Components Analysis (PCA) was performed to reduce the 13 dream variables into subsets of dream factors, rotated using the direct oblimin (oblique) with Kaizer Normalization. Assumptions for PCA were met: sample size exceeded 300 cases (Tabachnick & Fidell, 2013), and was deemed to be very good by the Kaiser-Meyer-Olkin (Kaiser, 1970) measure of sampling adequacy (KMO = .79). Intercorrelations were significantly different from zero, confirmed by Bartlett's Test of Sphericity ($p < .001$) and were not affected by multicollinearity, confirmed by the determinant of the *R*-matrix ($p = .003$). Factors with eigenvalues over 1 were retained (Kaiser, 1960). This led to a four-factor solution, accounting for 70.29% of the variance. The four factors were scrutinized and named:

Factor 1: Continuity with Waking-Life Dreams (6 items: Present Continuity, Recent Past Continuity, General Continuity, Similarity, Emotional Continuity, and Future Continuity)

Factor 2: Emotional-Important Dreams (2 items: Importance; Emotional Intensity)

Factor 3: Negative-Stressful Dreams (2 items: Emotional Valence; Stressfulness)

Factor 4: Hyperassociative Dreams (3 items: Distant Past Continuity; Metaphorical Continuity; Bizarreness)

Following identification of dream types, tests of difference were performed to analyse time spent asleep effects. Dreams from across the two nights were pooled, and dreams were split into two categories: "early night" dreams (from awakenings two and four hours after bedtime) and "late night" dreams (from awakenings six and eight hours after bedtime). This resulted in a total of 173 early-night dreams and 177 late-night dreams.

Factor 1: Continuous dreams: in support of the first hypothesis, a paired-samples *t*-test found that early-night dreams were more continuous with waking life (M=5.33, SD=1.73) than late-night dreams (M=4.36, SD=1.92), $t(59) = 3.49$, $p = .001$, $d = .53$, CI [.41, 1.51].

Factor 2: Emotional-Important dreams: in support of the second hypothesis, a paired-samples *t*-test found that late-night dreams were more emotional-important (*M*=4.23, *SD*=2.09) than early-night dreams (*M*=3.60, *SD*=2.01), *t*(58) = -2.30, *p* = .01, *d* = .31, CI [-1.20, -.08].

Factor 3: Negative-Stressful dreams: a Wilcoxon Signed-Rank test found that there was no difference between early- and late-night dreams in terms of negative valence and stressfulness, *T* = 873.00, *p* = .54.

Factor 4: Hyperassociative dreams: in support of the third hypothesis, a paired-samples *t*-test found that late-night dreams were more hyperassociative (bizarre, metaphorical, and recalled the distant past) (*M*=3.91, *SD*=1.54) than early-night dreams (*M*=3.28, *SD*=1.67), *t*(63) = -3.07, *p* = .001, *d* = .39, 95% CI [-1.03, -.22]. However, it can be observed that the constituent dimensions "bizarreness" and "metaphoricity" behaved different from "distant pant":

In sum, early-night dreams were more continuous with waking life than late-night dreams, whereas late-night dreams were more emotional and personally-important, and more hyperassociative, than early-night dreams. For some examples of early- and late-night dreams that illustrate these differences, see Supplementary Materials.

3.1.2 Correlations between dream variables

Pearsons correlational analyses were performed to investigate whether time orientation variance was greater in late- or early-night dreams. Tables 2 and 3 show the correlations between variables for the early (early+early-mid) and late (mid-late+late) awakenings, respectively.

A general pattern was discernible, whereby dreams in late-night sleep were more integrative: the correlations between the continuity measures were either the same, bigger than, or only significant for, the late dreams compared to the early dreams. For example, Recent Continuity significantly correlated with only Present Continuity and General Continuity in the early night, whereas in the late night it also significantly correlated with Distant Continuity, Future Continuity, Similarity, and Emotional Continuity. Similarly, Emotional Continuity only significantly correlated with Present and General Continuity in the early night, whereas in the late night it also correlated with Recent Continuity, Future Continuity, and Metaphorical Continuity. This pattern indicates more temporal hyperassociativity in the late-night dreams: those dreams refer to multiple time orientations in one dream, whereas in the early-night dreams time orientations appear in a more isolated fashion. Confirming this notion, Distant Continuity only correlated with another continuity variable (Recent Continuity) in the late night, and had moderately sized correlations (significant at the $p < .01$ level but which became non-significant after Holm-Bonferroni correction[1]) with Future Continuity and General Continuity.

The variable of dream "Importance" correlated only with one continuity variable, "Future Continuity", for both early- and late-night dreams, suggesting that dreams are deemed important when they are future-oriented rather than present- or past-oriented. Unsurprisingly, Importance also correlated with Emotional Intensity in both sets of dreams, but only correlated with Emotional

[1] This correction for Type I error was applied to all analyses.

Continuity and Stressfulness in late-night dreams. This sheds some light on the nature of emotional intensity across the night.

Another difference between the two sets of correlations concerns Metaphorical Continuity: Holm-Bonferroni-corrected significant correlations were found between this variable and Present and General Continuity in late- but not early-night dreams; and correlations significant at the $p < .01$ level were found between Metaphorical Continuity and Recent and Future Continuity in late- but not early-night dreams. This shows support for the third hypothesis, concerning hyperassociativity across the night, further demonstrating increased hyperassociativity as a function of time spent asleep.

[Insert Table 1 about here]

[Insert Table 2 about here]

[Insert Table 3 about here]

4.1 Discussion

Dream content varied as a function of time spent asleep. Dream reports from early-night sleep (the first four hours of sleep) were more obviously relatable to waking life across a number of time orientations, from recent past to anticipated future. Dream reports from late-night sleep (the second four hours of sleep), conversely, were more emotionally intense and personally important, and were more bizarre, metaphorical, and related to the distant past. Late-night dreams were also found to exhibit more time orientation variance: correlations between wake-dream continuity variables for different time orientations in the dreamer's waking life were bigger and more often statistically significant in late- than early-night sleep. The increase in bizarreness and metaphoricity, and in the intercorrelations between wake-dream continuity variables, indicate that late-night dreams were more hyperassociative than early-night dreams.

These across-the-night changes in dream content map in the expected ways onto cognitive sleep functions that vary as a function of stage of sleep. That early-night (non-REM-rich) dreams were found to be more relatable to waking life accords with previous findings that non-REM dreams tend to contain more episodic memories than REM dreams (Baylor & Cavallero, 2001), and together these findings support the notion that early night / non-REM dream transparently (Windt, 2013) reflect sleep-dependent episodic memory consolidation processes that occur during non-REM sleep (Born & Wilhelm, 2012). Likewise, that late-night (REM-rich) dreams were more emotional and personally important than early-night dreams accords with previous findings that REM dreams tend to be more emotional than non-REM dreams (Hobson et al., 2001; Smith et al., 2004), that late-night dreams become more emotional whether sampled from REM and non-REM sleep (Wamsley et al., 2007). These findings may reflect emotional memory consolidation and/or regulation processes that occur during REM sleep (Walker & van der Helm, 2009; Rosales-Lagarde et al., 2012). While some research has failed to find an effect of time of night on dream emotionality (Fosse et al., 2001; Malinowski & Horton, 2014), this may be due to the small sample sizes of these studies (N=9 and N=16, respectively).

We recognise that, whilst the activation of memories across different stages of sleep align with the present findings concerning early night (non-REM) and late night (REM) stages, that these coexisting trends are presumptive at present. Future studies aim to map empirically the stages of sleep onto time of night effects. Nevertheless, this does not devalue the contribution of understanding time spent asleep as a factor in sleep cognition. Indeed, time spent asleep may well contribute to an understanding of cognitive activity independently of sleep stage.

The current research found that late-night dreams were more hyperassociative than early-night dreams, as measured by bizarreness, metaphoricity, and time orientation variance. While previous studies have evidenced the increasing bizarreness of dreams across the night, and the increasing time orientation variance (Hobson, Pace-Schott, & Stickgold, 2000; Malinowski & Horton, 2014), this is the first to evidence increasing hyperassociativity measured with the alternative conceptualisation of 'metaphoricity'. (Although Malinowski and Horton (2014) measured metaphoricity also, a lack of power in that study led to a lack of significant effects, despite descriptive statistics conforming to the same trend.) ~~This finding too maps onto~~ Previous findings indicate that REM sleep, and not non-REM sleep, is crucial for creative, fluid, and associative kinds of wakeful thinking (Cai et al., 2009; Carr & Nielsen, 2015; Walker et al., 2002). While our results map on such findings to an extent in that there is more hyperassociativity in late-night sleep than early-night, we also found that here is some hyperassociativity in dreams at *all* sampled times of night. Taken together, the increase in bizarreness, metaphoricity, and time orientation variance of late-night dreams show several ways in which late-night sleep cognition tends to be more fluid, creative, and associative than early-night dreams.

Hyperassociativity has been explored here in terms of sleeping cognition featuring more than one original memory source, combined in at least one of a number of ways. Metaphoricity could reflect one memory source appearing as another; bizarreness could reflect one element of a waking memory appearing in the context of another; and time orientation variance reflects memory sources from one period of one's life appearing alongside sources from another. It remains to be explored whether hyperassociativity could emerge within a single memory source, as in Hartmann's (1996) conceptualisations of "loose connections", with one activated memory activating another, just in a less semantically associated way than waking, focused cognition would typify. Furthermore, the presence and characteristics of hyperassociativity across sleep stages, as well as time of night, requires further exploration.

The construct of "hyperassociativity" is one that is oft-used but as things stand remains poorly delineated. One of the aims of the present study was to investigate this construct using various theory-based operational definitions, and we confirmed our hypothesis that hyperassociativity would increase across the night using these definitions. In our previous research (Malinowski & Horton, 2014), we found evidence that metaphoricity and bizarreness may likely map onto a similar construct such as this owing to their very strong correlation. However, we did not replicate this finding; in the present study metaphoricity and bizarreness had much smaller, non-significant correlations. It is currently unclear why this would be so. Much more work is thus required to generate a commonly accepted definition of "dream hyperassociativity" and its constituent components.

It is suggested here that hyperassociative modes of sleep cognition – metaphorical, bizarre, and time orientation varied – underlie the REM sleep-dependent process of improving creativity and associative thinking in the waking state, but in future research this may be tested more directly. For example, it may be hypothesised that metaphorical, bizarre, and time orientation varied dreams may predict performance on creativity measurements. Likewise, it is suggested that the emotional content of sleep cognition underlies the REM sleep-dependent process of down-regulating emotional reactions, but this too needs to be empirically evidenced; emotionally intense dreams, for example, may be expected to predict down-regulation of emotional reactivity.

The methodology of the present study did not permit us to analyse whether wake-dream continuity decreased, and emotional intensity and hyperassociativity increased, across both non-REM and REM dreams as the night progressed. More research is needed to determine whether it is both non-REM and REM dreams that increase in hyperassociativity, or only REM dreams. Furthermore it is necessary to determine whether hyperassociativity exists within waking cognition also (e.g. during mind-wandering), or whether the "offline" and internally directed processing characteristic of sleeping cognition provides the necessary environment for associativity to prevail. Future studies aim to elucidate whether the time of night variations in dream content, continuity, emotionality and hyperassociativity are qualitative as well as quantitative, by exploring and controlling for dream length. We opted not to investigate dream report length in the current study in light of arguments that controlling for dream length is tantamount to controlling for the very features that are being measured (e.g. Hunt et al., 1993; Wamsley et al., 2007).

The study is based on self-ratings of dream content by participants. There is on-going debate regarding the optimal method of rating dream content. On the one hand, there is evidence that independent judges misjudge dream content such as bizarreness (Schredl & Erlacher, 2003) and emotion (Schredl & Doll, 1998; Sikka et al., 2014, 2017) in comparison to self-ratings. On the other, participants have been shown to misjudge the relative frequency with which they have different kinds of social interactions in their dreams in comparison to independent content analysis ratings

(Domhoff, 2003). We acknowledge that different results may be found with independent judges' ratings, but affirm that self-rating is more appropriate in this case owing to the subjective nature of the variables of interest (e.g. continuity with waking life, emotional intensity, bizarreness, etc.).

5.1 Conclusions

Dream content increases in emotional intensity and personal importance, and in hyperassociativity (as measured by metaphoricity, bizarreness, and time orientation variance) as a function of time spent asleep, but decreases in overt wake-dream continuity. These time of night changes in dream quality map clearly onto cognitive functions of sleep that differ according to stage of sleep: episodic memory consolidation in early night, non-REM-rich sleep; and emotional memory consolidation / emotion processing and creative thinking in late night, REM-rich sleep.

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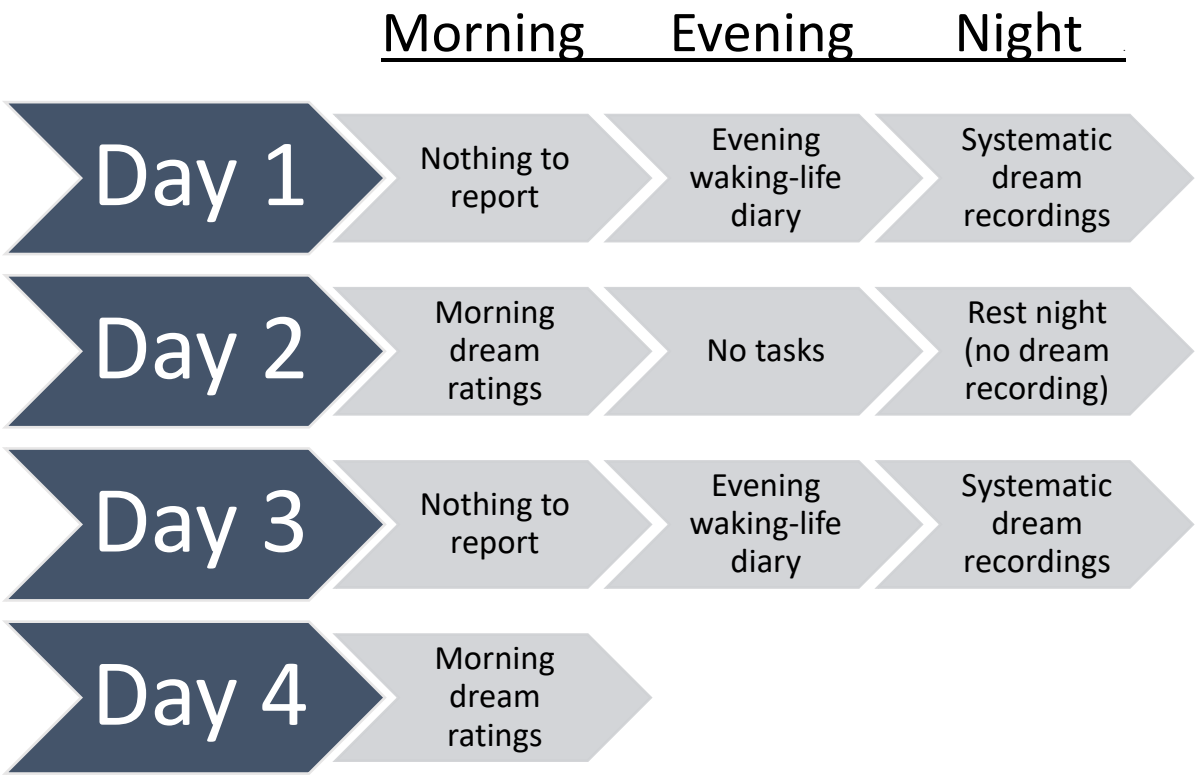

Figure 1. Experiment design. Participants proceeded through the tasks as described from top to bottom and then left to right.

Table 1 Means (and SDs) for the 13 continuity characteristics across time spent asleep

	early	early-mid	mid-late	Late
Present	6.08 (2.42)	5.94 (2.19)	4.85 (2.90)	5.40 (2.39)
Recent past	5.29 (2.74)	5.08 (2.27)	4.36 (2.80)	4.57 (2.57)
Distant past	2.89 (2.90)	3.21 (2.28)	3.40 (2.50)	3.28 (2.55)
Future	5.68 (2.65)	4.78 (2.77)	3.74 (2.60)	4.77 (2.37)
General continuity	6.13 (2.17)	5.64 (2.07)	4.44 (2.97)	5.46 (2.10)
Similarity	5.71 (2.37)	5.14 (2.21)	4.27 (2.60)	5.01 (2.24)
Metaphoricity	3.68 (2.62)	4.22 (2.34)	3.75 (2.32)	4.72 (2.37)
Emotional	5.78 (2.53)	5.53 (2.41)	4.78 (2.44)	5.31 (1.81)
Bizarreness	3.24 (2.66)	4.10 (2.77)	4.69 (2.52)	4.63 (2.64)
Emotional intensity	4.11 (2.22)	4.28 (2.31)	4.49 (2.64)	5.06 (2.26)
Emotional valence	0.35 (1.53)	0.63 (1.49)	0.03 (1.57)	-0.25 (1.60
Stressfulness	3.57 2.54)	3.18 (2.66)	2.43 (2.71)	4.29 (2.41)
Importance	3.17 (2.48)	3.26 (2.20)	3.06 (2.71)	4.35 (2.57)

Supplementary Analyses

Items	Factor				Dimension
	1	2	3	4	
Present Continuity	.83				
Recent Past Continuity	.82				
General Continuity	.86				Continuous with waking life
Similarity	.83				
Emotional Continuity	.44				
Future Continuity	.65				
Emotional Intensity		.87			Emotional-Important
Importance		.86			
Emotional Valence			.90		Negative-Stressful
Stressfulness			-.66		
Metaphorical Continuity				.63	
Bizarreness				.54	Hyperassociative
Distant Past Continuity				.80	

Factor loadings for Principal Components Analysis (PCA) on 4 dream content factors

Supplementary Materials: Dream Exemplars

Exemplar early-night dreams:

These early-night dream extracts illustrate content depicting waking-life continuity, with single themes within each dream and relatively neutral emotional tone.

Dream
"I was at work. We had orders coming in. I was cataloguing…I was replacing lots of cutters. There wasn't very much time, and there was some pressure to get the cutters replaced."
"I dreamt about I was going around buying several – lots of perfume and having a massive shopping spree."
"I was dreaming about the dog digging the garden. The cat doing some digging too. And I was also dreaming about running away."
"With people, stuff going on, I remember going down a muddy dirty track, being under a fence. I was really absorbed in what was going on. Sometimes in dreams I can feel quite stressed out, but it felt quite relaxed really."
"I'm not sure what I've been dreaming but I feel relaxed. I'm kind of, I feel like it's space, that space has moved, like a big room, a big space, but even though there was space, I'm not by myself. I don't know who these people are. But I feel alright. I feel comfortable. I feel very relaxed. I'm going back to sleep"

Exemplar late-night dreams:

These dream extracts illustrate multiple memory sources and hyperassociativity between recent waking-life continuities, more distant continuities and some discontinuities also. Furthermore these dreams contained a multiple simultaneous activities and events, building in emotional intensity throughout.

"It a big party with exams, the exams were actually happening at the party, people were getting called into a room one by one on their own. My partner turned up with his stupid car. Everyone was in sort of modern Victorian dress. Time was dancing, yeah time was actually dancing, not time spent dancing. The teapot from Beauty and the Beast was there. [Person] was there was well. I was happy. We were all in modern Victorian dress. Fireworks."
"I went to a water park. I don't know where it was, I've never seen it before. And the next thing I was in an room with all animals in tanks, and I had to try and save. And then I was back in the water park again, and I saw one of my dogs there and realised he was dead. It was pretty horrible."

"I was on a flight with my mum and my cousin Lisa. It was for some important business thing but I don't actually know what was actually going off, it was just an important thing. I think we were going to Iceland but the plane crashed five minutes after we took off, but it wasn't a like bad crash it sort of floated to the floor and then it landed, so no one was hurt. We landed in a building, but it was OK. No one was hurt, everyone got off the flight. They opened the safety doors on the side so everyone just went out that way. But then we had to go because we were doing something important, we had to go quickly so my mum got in her car because her car was where the plane had crashed. We got in her car with my cousin and myself, and then we were driving to find my Aunty Fran, and it was a really long drive and we were sort of panicking about stuff, and I was worried because I think my older sister had been on the plane when it crashed but she got home a different way I was worried if she was OK or not. And then we got to where my Aunty Val was but she was at my Aunty Kate's house, and my mum and my Aunty Kate don't like each other so when we got there it was a bit awkward, and mum was saying I don't know if I can come in, but then she was like you can, so we so my mum and my cousin and Aunty Fran and Aunty Kate went into the kitchen to talk about the serious thing that they were panicking about but I didn't I didn't know what it was. They were all in the kitchen walking about that, so I was sat in the living room with all of Aunty Kate's sons and daughters which are my cousins but I've not spoken to them for like 6 years so it was really awkward so I just sat stroking the dog on the settee. And then I think my mum shouted me so I went into the kitchen and my Aunty Kate and I think my cousin Lisa had gone out to sort something So my Aunty Fran and my mum were in the kitchen. Mum had had a cup of tea and was moaning that she'd had to use my Aunty Fran's cups and stuff and I told her to stop moaning and to stop being stupid. Then we left my Aunty Fran's house with my Aunty Kate and we got in the car and then I woke up."

"It was a really sunny day so I went with my younger sister and my boyfriend to a lake to go swimming in the water. On the way up we walked past – um – an old lady who had taken her two younger grand-daughters swimming as well. Um. We just walked past them then we went swimming in the lake. And then, um, we had loads of fun and then we had finished we went, we were sort of we walking back home and we were walking down the road and as we were walking home we walked past the, a house and outside there was a man getting stuff out of his car and taking it in to the house. And there was a little girl on the front garden and it was one of the girls, one of the granddaughters of the old lady we had passed at the lake. But she had red cuts and bruises and marks all over her face. So as we walked past I noticed, and I stopped and I said to the man, "what's wrong with her face?" And he said "oh, she's just had trouble a little bit", and I thought that's not a little bit that's a lot because she's got lots of bruises on her face, and he said "what are you trying to accuse me of?", and then he said I'm ringing the police, so we waited around for the police to come because obviously he'd hit her in the face or something cause she'd got bruises on her face. The police came and um they came with like a council worker as well and I said to them the little girls' face is all bruised and stuff, so they went inside with the council worker and the policeman went down the road. And then the council worker was talking to

the little girl and she said oh what happened to your face, how did you do that? And then she was being really quiet and the woman said, you're allowed to tell us what happened and the dad said that's OK you can tell them one thing that happened, and the council woman said that's not how it works. And then I didn't want to hear what she was saying so I went down the road to see where the policeman had gone and he was in a shop arresting someone who had just stolen something. And then I went back up to the little girls' house and the woman was putting her in the car and that she said that she'd email me what happens and I got an email ten minutes later saying the girl was staying with someone else in the family for six months because of what the dad had done. And then, and then I think I woke up."