Consciousness in sleep: How findings from sleep and dream research challenge our understanding of sleep, waking, and consciousness

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Abstract

Sleep is phenomenologically rich, teeming with different kinds of conscious thought and experience. Dreaming is the most prominent example, but there is more to conscious experience in sleep than dreaming. Especially in NREM sleep, conscious experience, sometimes dreamful, sometimes dreamless, also alternates with a loss of consciousness. Yet while dreaming has become established as a topic for interdisciplinary consciousness science and empirically informed philosophy of mind, the same is not true of other kinds of sleep-related experience, nor is it true of sleep itself. I argue that this is a mistake. Conscious experience in sleep is more diverse than dreaming and we need to explain its different forms as well as the alternation between conscious and unconscious sleep states. We also need to ask how different kinds of sleep-related experience relate to foundational issues about sleep and wakefulness as well as sleep stages. I survey recent findings and theoretical developments from sleep and dream research to show how the traditional view of sleep and its relation to wakefulness and consciousness is flawed. I then suggest that by refining our frameworks of sleep-related experiences and sleep staging in tandem, we can work towards a better view. As we are only beginning to understand the diversity of consciousness in sleep, an important aim is programmatic: We need a philosophy of sleep and of consciousness in sleep, not just a philosophy of dreaming, and a future theory of sleep needs to integrate phenomenological considerations with neuroscientific and behavioral evidence. Working towards such a theory will radically transform our understanding of sleep, wakefulness, and our conscious minds.

Keywords:

Sleep, sleep stages, local sleep, dreaming, dreamless sleep, wakefulness, consciousness

Introduction

Long a boutique topic, dreaming is now firmly established as a target for interdisciplinary consciousness science and empirically informed philosophy of mind. The same is not true, however, for sleep. Philosophical interest in sleep tends to be focused on its association with dreaming. When mentioned on its own, sleep is often portrayed as the opposite of waking and of consciousness (Searle, 2000; Tononi, 2008). This would seem to imply that dreamless sleep hovers on the borders of consciousness science and philosophy of mind but falls outside of their purview.

This situation is symptomatic of the often implicit idea that sleep is both all-too familiar and interesting mostly for what it lacks. The obvious candidates for such a negative characterization include conscious experience, overt behavior, and ability to react to external stimuli. But new findings and theoretical developments suggest that this traditional view is misleading: we think we know what sleep is, but in a number of important ways, we are only just beginning to find out. Consciousness science is increasingly engaging with these findings, but philosophy has been slow to follow suit.

In this paper, I argue that sleep should be a primary research target for philosophy and interdisciplinary consciousness science: we need a philosophy of sleep and of consciousness in sleep, not just a philosophy of dreaming. Along the way, we will gain important insights on the variability, richness, and subtleties of sleep-related experience; we will likely also have to revise our taxonomy of mental states, including our understanding of sleep and wakefulness themselves.

I begin by reconstructing the traditional view of sleep and how it has already changed in response to scientific findings. I propose that so-called simulation views of dreaming can help the field move forward. They promise a phenomenological framework in which dreaming is defined independently of sleep stages while also forming a point of departure for identifying kinds of sleep experience that can be described as dreamless. Together with advances in the neuroscience of sleep, including sleep staging and sleep disorders, this framework can guide a novel conception of sleep and sleep staging and lead us towards a theory that unites the subjective and objective sides of sleep. To show how, I consider empirical evidence on sleep onset, state dissociations, and local sleep. I suggest radical revisions to the traditional concept of sleep, wakefulness, and conventional sleep staging are needed and identify questions for future research.

The traditional view of sleep

Sleep has traditionally been thought of as a naturally and regularly occurring period of passivity and rest that affects the entire organism, including behavior and responsiveness to external stimuli as well as the occurrence and contents of subjective experience. Defined by the absence of behavior, perception, and (with the exception of dreams) consciousness, sleep is also commonly regarded as a uniform state and the opposite of wakefulness.

In this section, I take a bird's eye view on the history of sleep and dream research, tracing how the elements of the traditional view of sleep have been adapted to accommodate new findings. Despite these refinements, the basic ingredients of the traditional view have largely remained intact. Moreover, while sleep and dream research are often considered as separate fields (Kroker, 2007), this division is artificial, and how sleep relates to consciousness (including dreams) is and always has been a central question for the definition and scientific study of sleep.

The traditional view of sleep, still found in dictionary definitions, dates back to antiquity. Aristotle (1990) characterized sleep through a global loss of perception and promoted a dichotomy between sleep and wakefulness in which sleep is quite simply the absence of wakefulness. Later this dichotomy was extended to cover the contrast between sleep and consciousness, which in line with behaviorism was equated with wakefulness (Malcolm, 1959). For a long time, this negative view of sleep discouraged systematic research, conveying the impression that in sleep, there was nothing interesting to observe (Kroker, 2007). It finds its starkest expression in the description, again of ancient origin, of sleep as the little brother of death.

Sleep science has added complexity to the definition of sleep but largely preserved the main ingredients of the traditional view. Behaviorally, sleep is characterized by immobility, relaxed posture, and reduced responsiveness (Peigneux et al., 2001; Siegel, 2009); it is also described as easily reversible and homeostatically regulated, meaning that sleep loss results in increased duration, depth, or consolidation of sleep (Cirelli & Tononi, 2008). At the same time even basic questions concerning the functions of sleep and its ubiquity in all animals remain controversial (Cirelli & Tononi, 2008; Siegel, 2008).

The behavioral criterion of unresponsiveness has been supplemented with brain-based criteria for identifying different sleep stages. With the discovery of REM (rapid eye movement) sleep (Dement & Kleitman, 1957), sleep was seen to have a complex architecture in which the stages of NREM (or Non-REM) sleep, which stretch from sleep onset to deep sleep, are followed by REM sleep (Pace-Schott, 2009). NREM sleep is marked by synchronized slow-wave

activity, whereas REM sleep is marked by desynchronized fast activity that is nearly indistinguishable from waking EEG. Muscle tone decreases in NREM sleep as compared to wakefulness and reaches its low-point in REM sleep. This state of near-paralysis contrasts with rapid eye movement activity. It also contrasts with reports of rich subjective experiences, which are much more likely to follow awakenings from REM than from NREM sleep.

Throughout the night, we follow a standard trajectory through the stages of NREM sleep, followed by REM sleep, a return to NREM sleep, and so on; sleep is also interspersed with numerous awakenings, often too short to be recalled. The associated physiological changes are highly orchestrated and regulated by the ascending reticular activating system. Each sleep cycle takes about 90 minutes, but with increasing sleep duration, the deeper stages of NREM sleep disappear and give way to longer REM periods. The longest and most complex dreams occur in the morning, close to awakening.

The discovery of REM sleep in the 1950s marked the beginning of both sleep and dream science. The association of REM sleep awakenings and dream reports, coupled with a comparative paucity of dream reports following NREM sleep awakenings, led early dream researchers to optimistically regard the physiological characteristics of REM sleep as objective markers of the occurrence and duration of dreaming (Dement & Kleitman, 1957). The supposed identification of dreaming and REM sleep led to the view of NREM sleep as unconscious, dreamless sleep. These findings initiated a profound shift in the concept of sleep: NREM sleep inherited the negative definition that had previously been applied to sleep in general. By contrast, to make sense of the occurrence of conscious experience in sleep, dreaming was confined to REM sleep and assigned a category of its own. REM sleep was "neither sleeping nor waking. It was obviously a third state of the brain, as different from sleep as sleep is from wakefulness" (Jouvet, 2000, p. 5).

This notion of waking, REM, and NREM sleep as the three cardinal states of the brain and mind continues to be widespread. For example, it is central to the influential AIM model (Hobson et al., 2000), which attributes transitions from waking via NREM to REM sleep, including changes in conscious experience, to concerted changes in the overall level of brain activation (A), information processing/input source (I), and neuromodulation (M). The AIM model preserves the original idea of waking, REM and NREM sleep as global states, assuming isomorphism on the phenomenological, behavioral, and neuronal levels.

The idea that sleep, wakefulness, and sleep-stages are multilevel, whole-brain phenomena that can be unambiguously categorized and are mutually exclusive is popular to this day (Siclari

& Tononi, 2017). The picture has become more fine-grained, differentiating three states where previously there were thought to be just two, while preserving the main assumptions of the traditional view of sleep.

The traditional sleep-wake dichotomy also resurfaced in consciousness science in the form of a dichotomy between consciousness, associated with both waking and dreamful sleep, and unconscious, dreamless sleep. In this context, consciousness refers to the global phenomenon of being conscious at all, not to particular contents of consciousness (such as tasting pistachio ice cream or seeing a toddler smile). Used in the former sense, consciousness is often operationally defined as that which disappears in deep, dreamless sleep and reappears in waking and dreaming (Searle, 2000; Tononi, 2008). A similar idea is found in work on global states, background states, or modes of consciousness, where REM sleep/dreaming is contrasted with presumably unconscious NREM sleep (for details and critical discussion, see Bayne et al., 2016). Because sleep isolates consciousness from potential confounds arising from outward behavior and external stimulus processing that accompany consciousness in waking, the contrast between dreamful and dreamless (presumably unconscious) sleep has also been proposed as a research model of consciousness (Churchland, 1988; Revonsuo, 2006) and led to specific experiments probing the neural correlates of consciousness (Siclari et al., 2017; Tononi & Massimini, 2008).

The aspect of the traditional view that has undergone the most radical transformation is the characterization of sleep as passive and inactive. On the whole, findings on sleep architecture and sleep homeostasis (Cirelli & Tononi, 2008) have shown the progression of sleep stages to be actively orchestrated. Yet the view of sleep as passive rest was partially redeemed through the distinction between REM sleep/dreaming on one hand and unconscious NREM sleep on the other hand, alongside the view that sleep proper is confined to NREM sleep (Jouvet, 2000). Passivity, in relation to NREM sleep, refers to the presumed absence of mental activity and conscious experience. By contrast, REM sleep is highly active on measures of brain activity and subjective experience. Areas associated with visual and motor experience and emotions are even more active in REM sleep than in waking, which in turn fits in well with the visual, action-packed, dynamic, and emotional character of many dreams (Desseilles et al., 2011). This stands in stark contrast to the fact that external stimulus processing and muscle tone reach their low point in REM sleep (this is also often called the sensory input and motor output blockade; Hobson et al. 2000); in this sense, REM sleep is deeper and more behaviorally passive than NREM sleep. This contrast between outward passivity and rich subjective experience is reflected in the occasional designation of REM sleep as paradoxical sleep (Jouvet, 2000).

In sum, while the traditional view of sleep has been updated in response to scientific discoveries, many of its key assumptions have been preserved. Moreover, from the beginning of sleep science, conceptions of sleep and sleep stages have been intertwined with considerations on conscious experience and dreaming. Recurring themes include the tendency towards drawing sharp, mutually exclusive distinctions between sleep and wakefulness as well as between sleep stages; the tendency to regard them as whole-brain phenomena and global states in which changes in behavior and neural processing are aligned with changes in experience; and the idea that sleep, with the exception of dreaming, is uniformly unconscious. In the remainder of this paper, I argue that recent findings and theoretical developments in the fields of sleep and dreaming cast doubt on these assumptions, making even the updated view of sleep and sleep staging seem insufficient.

Simulation and beyond: From dreaming to dreamless sleep experience

Initial hopes of using REM sleep as an objective marker of dreaming were soon frustrated. Sleep research split off into its own field and to this day remains largely separate from dream research. The proposed identification of REM sleep and dreaming was found to be flawed: dream reports do not always follow REM awakenings and following brain damage, dream recall can even be selectively lost without disturbance to REM sleep (Solms, 2000, 2014); dreams are also recalled with varying frequency following NREM sleep (Nielsen, 2000).

In addition to persistent controversy about the sleep stage correlates of dreaming, dream research was long hampered by different definitions. Some researchers defined dreaming broadly as any kind of conscious thought or experience during sleep; others defined dreaming narrowly as vivid, emotionally intense and narratively complex experiences occurring in sleep (Nielsen, 2000; Pagel et al., 2001).

These conflicting positions mean different phenomena are classified as dreaming by different groups. In the persisting debate on the sleep stage correlates of dreaming, narrow definitions tend to be associated with the idea that dreaming is dependent on REM sleep mechanisms, whereas broader definitions more naturally fit the view that dreams occur in all sleep stages (Nielsen, 2000). Lack of definitional clarity also introduces ambiguity to the relation between dreaming and consciousness. If dreaming broadly involves any experience in sleep, dreamless sleep is by definition unconscious. If dreaming narrowly involves specific sleep experiences, it is an open question whether dreamless sleep experiences exist. Similarly, NREM sleep may or may not be considered synonymous with (unconscious) dreamless sleep.

An important methodological innovation that sheds new light on the relation between conscious experience and sleep stages are serial awakening paradigms (Noreika et al., 2009; Siclari et al., 2013). Participants are awakened at short time intervals from different sleep stages, yielding many more reports than traditional paradigms, in which participants are awakened only 4-5 times per night during REM periods. This method therefore provides richer evidence about the frequency and distribution of conscious experience across sleep stages. Findings suggest that while REM sleep and the early stages of NREM sleep are marked by high levels of recall, in the deeper stages of NREM sleep, there are roughly equal proportions of recall of conscious experience, no recall, and so-called white dreams, in which participants have the impression of having had conscious experiences before awakening but are unable to recall any details (Noreika et al., 2009; Siclari et al., 2013). In one study, recall of conscious experience was associated with activity in the parieto-occipital areas in the sleep period preceding awakening. This was true both for NREM and REM sleep, suggesting that local changes in neural activity might be the neural correlate of dreaming independently of sleep stage (Siclari et al., 2017; Siclari & Tononi, 2017).

If we assume that these reports reflect the presence versus absence of experience during sleep (Windt, 2015; Windt, 2013), then the deep stages of NREM sleep in particular appear to be phenomenologically diverse. Because of this diversity, the study of NREM sleep seems ideally suited for investigating fluctuations between conscious experience and unconscious sleep. This stands in stark contrast to the historical fixation on REM sleep and the comparative neglect of NREM sleep in a majority of dream studies.

White dream reports might be particularly interesting in this regard. While some white dream reports might result from forgetting, others might involve a transitional state between unconscious sleep and more fully formed dreams; we might speculate that in this transitional state, experience is taking shape but lacks the richness and complexity that would allow us to remember or report any details (Fazekas et al., 2018; Windt, 2015b). These states might provide a glimpse of the simplest form of conscious experience. An intriguing possibility is that targeted questions or training might make the difference between these subtypes of white dreams—if they exist—show up in reports. For example, reports of having forgotten a long, complex dream would indicate the occurrence of a different subtype than reports that describe the presence of experience that lacked specific thought contents or imagery, and where the participant did not describe the feeling of having forgotten more details.

More generally, if conscious experience in sleep—and with it dreaming—is cast adrift from REM sleep, this highlights the need for a precise taxonomy of sleep experience. Simulation

views, which are increasingly gaining traction in dream research and philosophy, are an important step in this direction (Revonsuo et al., 2015). Their key claim is that dreaming is at core simulational and immersive: dreams are vivid *here* and *now* experiences, or experiences of a world centred on a self.

Different simulation views focus on different aspects of dreaming. At a very general level, the immersive structure of dreaming mimics that of waking experience, suggesting that dreaming reveals consciousness itself "first and foremost as a subjective world-for-me" (Revonsuo, 2006, p. 75). For the same reason, dreaming is sometimes described as a 'gold standard' to which designers of virtual environments should aspire (Moller & Barbera, 2006).

Other kinds of simulation view focus on more specific aspects of dream experience. Most dream reports describe the presence of several dream characters experienced as distinct from the self, and dream reports actually contain more descriptions of social interactions than randomly timed waking reports. This leads to the claim that dreams simulate rich social environments and possibly support social cognition (Revonsuo et al., 2015).

Another focus is the dream self and the relation of self-experience to conscious thought and bodily experience. For example, one can ask what are the typical characteristics of self-experience in dreams and how (if at all) they differ from waking (Revonsuo, 2005); or one can investigate the variability of self-experience within dreams and attempt to identify the minimal conditions for its emergence (Windt, 2015; Windt, 2018). Vicarious dreams, in which we dream of being a different person (such as a fictional or historical character) are an interesting in-between example (Rosen & Sutton, 2013).

Another question concerns the sources of self- and world simulation in dreams. Because in dreams, self- and world-experience seems to arise largely independently of real-world input, dreams are often argued to support internalism about experience (Rosen, 2018; Windt, 2017). Yet the claim that dreams are completely divorced from outward behavior and perception is oversimplified. The processing of external stimuli seems to fluctuate throughout sleep (Andrillon, 2016), and in dreams there are varying degrees of concordance between sensory input, imagery, and motor output (Windt, Nielsen, & Thompson, 2016). Internally generated imagery may exist alongside illusory misperception and in some cases even veridical perception, where these can merge seamlessly with the ongoing dream. Sensations from the sleeping body, including sensory feedback from muscular activity but also, for instance, sounds can shape ongoing dream experience. Taken together this challenges the classical description of sleep, and especially of REM sleep/dreaming, as a state in which behavioral responsiveness is uniformly

lost and the mind is essentially left to its own devices, cut off from perception of and interaction with the external world (J.M. Windt, 2017).

Different versions of the simulation view of dreaming are largely complementary and there is sufficient convergence between them to forge conceptual unity in the field. Unlike narrow definitions of dreaming that are often catered towards REM sleep dreams (which tend to be longer and more narratively complex, as well as more bizarre than NREM dreams (Carr & Solomonova, n.d.), immersive *here* and *now* experience characterizes dreams from all sleep stages. At the same time, not all sleep-related experiences are immersive, and again there is variation within sleep stages. Simulation views therefore both define dreaming independently of sleep stages and form a starting point for identifying kinds of sleep experience that do not count as dreamful (Windt, 2015b; Windt et al., 2016). Without *here* and *now* experience, there can be no sense of presence, and without a self to center it, one cannot meaningfully speak of the appearance of a world. Windt (2010, 2015a) has argued that minimal phenomenal selfhood in dreams coincides with minimal dreaming and both are constituted by spatial and temporal self-location, or the phenomenal *here* and *now*. Experiences in sleep that lack these features therefore count as dreamless sleep experience.

Candidates for dreamless sleep experience (Windt, 2015b; Windt et al., 2016) include propositional thought (in the form of sleep thinking), bodily experiences, residual perceptual experiences, and isolated imagery where these occur on their own independently of a larger hallucinatory context or simulated scene. Different kinds of dreamless sleep experience can be distinguished; overall, such non-immersive experiences seem to be most frequent at sleep onset and in NREM sleep. In addition, we can envisage even simpler forms of experience arising independently of propositional thought, imagery, or bodily sensations. In these states, even basic forms of the self-other distinction would have dissolved; there would no longer be a felt difference between *me* and *not me* or *here* and *there*. Such states would be phenomenologically selfless (Windt, 2018) but might still involve minimal phenomenal experience (Windt, 2015b), or the simplest conceivable form of phenomenal experience; they would then function as a point of transition between immersive and hence dreamful experience and unconscious sleep.

Minimal phenomenal experience has now turned into a broader research project. Inspired by Thompson's (2014, 2015a) analysis of dreamless sleep, Windt (2015b) describes minimal phenomenal experience as purely temporal experience in which a phenomenal *now* plus a sense of duration is preserved; in this view, temporal experience is both necessary and sufficient for phenomenality. Thompson (2015b) suggests that minimal phenomenal experience

might involve the bare feeling of being alive; Metzinger (2018) proposes that it is linked to the feeling of wakefulness and arousal.

While dreamless sleep experience has not, so far, been widely discussed in the contemporary literature, it was a center of debate in classical Indian philosophy (Thompson, 2014, 2015a). The debate arose from the question of how we can know upon awakening from a deep and dreamless sleep that we have slept peacefully. One school argued that such reports are inferential and dreamless sleep is unconscious. Another argued that consciousness persists throughout sleep and these are genuine memory reports. In this view, the absence of thought contents and imagery can be both experienced during sleep and remembered after awakening. Indeed there is evidence that experienced meditators report conscious awareness during dreamless sleep; they also have distinct brain rhythms in slow wave sleep that are not found in non-meditators (Ferrarelli et al., 2013).

The persistence of meta-awareness in dreamless sleep can be described as a deep-sleep analog of lucid dreaming. In lucid dreams, dreamers become aware they are dreaming and often have some level of dream control (Voss et al., 2013; Voss & Hobson, 2015). Sometimes, lucid dreams even shade into lucid dreamless sleep. Reports sometimes describe the dissolution of the sense of self as well as of space and time (Windt, 2015b). Like meditators, these dreamers might be witnessing the waxing and waning of dreamful and dreamless experience in sleep.

What about nonlucid dreamless sleep experiences? Such experiences would not involve meta-awareness of sleep; unlike reports of witnessing dreamless sleep from experienced meditators and reports of lucid dreamless sleep from lucid dreamers, they might therefore not be retrospectively described as sleep experiences at all. A subgroup of white dreams, or reports of having had experiences but being unable to recall any details, might fit this profile. As suggested earlier, the lack of detail in these reports might reflect the phenomenology of these states: if some white dreams involve the persistence of experience with minimal content, but lack specific kinds of imagery or thought contents, this would result in a lack of reportable detail after awakening. White dream reports describing such experiences would require that subjects could recall, upon awakening, *that* they were conscious—but there would be no further details about the experience that they could recall or describe.

Another example of dreamless sleep experience, possibly involving a minimal form of phenomenal experience, might be sleep-state misperception, in which people claim they have been awake even though according to EEG and behavioral criteria they have been asleep. Sleep-state misperception can occur in healthy individuals (Sewitch, 1984; Webb, 1975) but is

particularly pronounced in insomnia. In addition to objective sleep loss, subjective insomnia involves overestimation of sleep onset latency and underestimation of total sleep time (Harvey & Tang, 2012). An intriguing possibility is that this mismatch between subjective and objective sleep quite literally involves misperceiving sleep as wake: if certain forms of experience (including minimal phenomenal experience) occurred more frequently in certain people—or if certain people had heightened awareness of their occurrence—, and if these experiences were not easily identified *as* sleep-related experiences (as is the case for many dreams), this might lead them to believe they were awake when objectively they were asleep. Indeed, one theory links sleep misperception to heightened effort and intention to sleep, alongside heightened awareness of sleep onset and monitoring of external cues (Espie et al., 2006). Moreover, mindfulness training may improve subjective insomnia (Bei et al., 2013; Ong et al., 2012). It is tempting to speculate that sleep misperception and witnessing sleep are mirror images involving nonlucid and lucid dreamless sleep experience; both would be associated with the same type of experience, but only the latter would additionally involve awareness that this experience is occurring in sleep.

Whether or not these are genuine instances of minimal phenomenal experience arising in dreamless sleep, it is clear that objective measures of sleep through behavior and EEG can be dissociated from what is subjectively described and experienced as sleep. As one subject put it, "there is for me a state which may be technically sleep to you, but is wakefulness to me and, uhh—it's an intermediate state—it's very hard to define, uhh—but I definitely felt that it's there—and uhh—uhh none of the questions precisely examined this situation." (Sewitch, 1984, p. 257). Future research will need to take the subjective experience of sleep seriously, and doing so might help make progress not just in consciousness science, but also on the diagnosis and treatment of sleep disorders such as insomnia.

What is less clear is how to resolve cases where subjective and objective measures of sleep come apart and whether to say that they do or do not count as sleep. Such cases illustrate the limitations of overly rigid sleep-stage scoring but also put pressure on the sharp dichotomy between sleep and wakefulness. Conscious experience might be more like a dimmer than a simple on-off switch, with intermediate states and fluctuations between conscious and unconscious states that cut across sleep stages and sleep/wake states as commonly defined. A more precise framework might be needed to tease apart these changes in subjective experience and align them with objective changes. Yet in some cases, it might be best to resist unambiguous classification of their occurrence in waking or sleep. Examples of dissociation between subjective and objective measures of sleep might be evidence of genuine in-between states in which a

simple, straightforward answer to the questions of whether they occurred in waking or sleep would remain elusive even if a more precise, multilevel framework were in place.

Unifying subjective and objective sleep: How sleep-wake transitions, state dissociations, and local sleep challenge the sleep-wake dichotomy

Just as we need a more precise framework for describing changes in subjective experience in sleep, we also need more precise criteria for distinguishing sleep stages and even sleep and wakefulness themselves. I propose that developing these in tandem might help align subjective sleep experiences with sleep stages, much as early dream researchers envisioned. In this section, I survey three examples of how greater precision on the side of sleep staging might align with a more precise phenomenological framework, as offered by simulation views.

But first, the focus of this approach on experience reports requires me to consider an objection: by working towards a unified conception of the subjective and objective side of sleep, my proposal may seem to lead in the wrong direction, away from greater objectivity. There is truth in this, but I would argue this is a strength, not a weakness. This is not the place to launch an extended defence of the trustworthiness of dream reports, so I will just offer a few remarks here (for details see Windt, 2013, 2015a,b).

First, while trusting retrospective sleep-experience reports is built into my proposal, this does not mean anything goes. Reports following laboratory awakenings, which can then be related to polysomnographic measurements from the preceding sleep stage, are the gold standard of dream research (Windt, 2013, 2015a). These likely paint a more accurate picture of the occurrence and absence of sleep-related experiences than spontaneous dream recall, where people report what they recall after awakening in the morning; this latter method is likely biased towards dreams occurring before awakening as well as long and emotionally intense dreams. Individual dream reports are also different from general questionnaires asking participants how often they dream or experience particular emotions, contents etc. in their dreams. Such generalizations might easily be eschewed by people's opinions about dreams. Moreover, dream research continues to provide evidence on which factors influence dream reporting, ranging from how participants are awakened to how dream reports are scored. Use of specific questionnaires or training participants may further help improve reports. Ideally, to build a framework of sleep-related experience, research would focus on reports gathered under ideal conditions and would strive to further optimize these conditions.

Second, the assumption that dream reports (at least when gathered under certain conditions) are trustworthy is built into dream research. Even where findings from one kind of

study (using one kind of dream report, scoring method etc.) are used to criticize another set of findings, this will often be related to a methodological discussion (as in the discussion on dream emotion; see Merritt, Stickgold, Pace-Schott, Williams, & Hobson, 1994; Sikka, Valli, Virta, & Revonsuo, 2014). The same is true for efforts to predict the occurrence and/or contents of sleep-related experiences (Horikawa et al., 2013; Siclari et al., 2017). Even if researchers remain completely blind as to whether participants reported having conscious experiences or being unconscious before awakening, and attempt to predict the presence or absence of conscious experience based on nothing other than objective polysomnographic data, access to subjective reports is still crucial for assessing the accuracy of these predictions (Wong et al., 2019).

Third, the attempt to find sleep stage correlates of conscious (presumably dreamful) vs unconscious (presumably dreamless) sleep was central to the original distinction between REM and NREM sleep, which was the beginning of modern sleep staging and sleep science. Striving for a unified model of subjective and objective sleep that can overcome conceptual issues in the definition of dreaming as well as known problems related to current sleep staging therefore seems desirable.

In this context, it is important to realize that there is much arbitrariness even in conventional sleep-staging. Where today it is common to distinguish three stages of NREM sleep, NREM sleep used to be divided into four stages (Silber et al., 2007; *Sleep Stage Scoring*, 2019). In 2007, as part of a major review of the sleep scoring criteria that had been used since 1968, former stages 3 and 4 of NREM sleep were integrated into a single stage called N3. The reasons for this were complex (Silber et al, 2007), but one upshot was that where NREM 3 had previously been defined through the presence of 20-50% delta (or slow wave) activity and NREM 4 through more than 50% delta activity, the range of delta activity in the newly formed N3 now covered an even larger range from 20-100% delta activity. Insofar as the neural correlates of dreaming are concerned, this move towards more coarse-grained stages might mask within-stage differences—which is consistent with the high frequency of reports both of dreaming and unconscious sleep from that sleep stage. This is especially true as local decreases in delta activity have been suggested to predict the occurrence of dreams (Siclari et al., 2017; but see Wong et al., 2019).

Even the distinction between REM and NREM sleep might not be as sharp as these labels suggest. Nielsen (2000) proposed that covert REM sleep, or REM-like activity in NREM sleep that is below the threshold for being scored as REM sleep, might explain dreams occurring outside of REM sleep as conventionally defined.

There is an element of arbitrariness in even the most basic conventions of sleep stage scoring. To this day, sleep is commonly scored in 30 second epochs. Back when early dream researchers printed polysomnographic recordings (typically including sleep EEG, muscle tone, eye movements, blood oxygen, heart and breathing rate) roughly 30 seconds fit on a sheet of paper (Schulz, 2008; *Sleep Stage Scoring*, 2019). So the size of paper determined a basic convention of sleep stage scoring that is followed to this day.

Research on sleep onset illustrates what a move towards greater precision might look like. Sleep onset spans the period from drowsy wakefulness through NREM 1 and early NREM 2, lasting no more than a few minutes. Back in the late 1990s, an alternative scoring system was proposed in which 9 substages are distinguished within that same period (Tanaka et al., 1996). These substages are characterized by distinct patterns of EEG activity. Intriguingly, they might also map onto different stages of sleep onset experience.

The twilight zone between sleep and waking teems with subjective experience, and experience changes in characteristic ways as we move from waking into sleep. During sleep onset, there is a progression from simple, unimodal, and snapshot like imagery to fully formed imagery involving visuospatial scenes and spanning longer episodes that tend to be dynamic and narratively organized (Nielsen, 2017; Windt, 2015a). Sleep onset imagery is often accompanied by changes in bodily experience (e.g. the dampening of sensations from the body and the bedsheets), movement illusions (such as sensations of falling, floating, or separating from the physical body), and feelings of paralysis (Cheyne & Girard, 2007). The later stages of sleep onset experience are often immersive and dream-like, leading to their description as oneiragogic experiences, or literally, experiences *leading into dreams* (Windt, 2015a; this is in contrast to the more common term of hypnagogia, which describes sleep onset, or the period *leading into sleep* as well as associated experiences). Nielsen (2017) refers to sleep onset experiences as microdreams and suggests that by disentangling the factors underlying their formation, we can gain insights into the formation of full-fledged dreams. In addition, research on sleep onset is also a model of how research on sleep staging and its relation to dreaming and dreamless sleep experience could progress, namely by identifying finer-grained sleep stages that are both polysomnographically defined and phenomenologically salient. Greater precision, in this context, involves reducing the time-frame occupied by individual (sub)stages as well as reducing variation of EEG activity on the one hand, and of phenomenological categories on the other hand.

Another lesson to draw from sleep onset, however, is that in the process of making both sleep staging and our taxonomy of sleep-related experiences more fine-grained, the distinction

between sleep and waking themselves will not necessarily become sharper. To the contrary, higher temporal resolution of sleep staging, coupled with more detailed phenomenological categories, might only highlight the continuity in both experience and brain activity as we move from waking into sleep and vice versa. Sleep-wake transitions seem to be not abrupt but are often smeared, shading into each other and perhaps even involving periods of overlapping and ambiguous activity.

The sleep-wake dichotomy is threatened not just by gradual transitions during sleep onset, but also by cases involving large-scale or partial dissociations. Perhaps the most radical example is status dissociatus, involving a dissociation between sleep and waking on the levels of brain activity, behavior, and experience. Status dissociatus is characterized by a near-complete breakdown of state-determining boundaries: REM and NREM sleep stages as defined by conventional scoring criteria are absent. There are also extreme fluctuations in attention, confabulation, and mental confusion, as well as outward enaction of dream behavior (Antelmi et al., 2016; Mahowald, Cramer Bornemann, & Schenck, 2011; Mahowald & Schenck, 1991). Patients with this disorder are stuck in a borderland between sleeping, dreaming, and waking without ever truly occupying any of these states.

More benign examples of dissociation exist as well. Many parasomnias such as sleep walking, sleep talking, and other sleep behaviors involve dissociation between sleep- and wake-related processes, leading to partial arousal and often stereotyped but complex behaviors during sleep (such as cooking, sex, or even driving) (Castelnovo et al., 2018; Irfan et al., 2017).

But dissociation also exists in healthy sleep. When sleeping in an unfamiliar environment—a hotel room, a new house—many people have the feeling of being half awake throughout the night. Similarly, participants in sleep laboratory studies show changes to sleep architecture during the first night; as these tend to disappear on subsequent nights, this is called the first-night effect. One study (Tamaki et al., 2016) found evidence for a difference in slow wave activity between the hemispheres that occurred only during the first night. It was almost as if half of the brain was less deeply asleep than the other. Importantly, the hemisphere that was less deeply asleep showed an increased response to sounds, especially when they were unexpected; this was also associated with more frequent arousals and faster behavioral responses than on subsequent nights. The authors suggest that the first-night effect is linked to half of the brain keeping watch when sleeping in an unfamiliar environment. Apparently, sleep depth can be unevenly distributed, and these local changes are linked to behavioral responses during sleep. This challenges the idea that the appropriate unit for scoring wake and sleep stages is the entire

brain; a more precise scoring system might also have to enhance its spatial resolution to bring regional differences in brain activation into focus.

This is especially true as sleep depth can also be unevenly distributed on a smaller scale, and in sleep research, so-called local sleep is turning into a hot topic. Recent research shows that there can be regional differences especially in slow wave activity. Local differences in slow wave activity have been found in NREM sleep, but also in REM sleep and even in wakefulness (Bernardi & Siclari, 2019; Siclari & Tononi, 2017). This means there can be differences in sleep depth within a single sleep stage; activity characteristic of NREM sleep can occur locally in REM sleep; and even during wakefulness, parts of the brain can be asleep. Local sleep is local in both time and space, involving a change in slow wave activity that occurs on the level of neuronal networks and is short-lived (lasting no more than 5 seconds). This is in contrast to conventional sleep stages that are defined through global (i.e. whole-brain) changes in EEG activity, consistent with the poor spatial resolution especially of traditional EEG.

Local sleep, even more so than the examples discussed so far, challenges the traditional view that sleep and wakefulness are sharply distinct global phenomena. For the regulation of sleep depth, neuronal assemblies rather than the entire brain seem to be the fundamental level, and whole-organism sleep appears to be an emergent property (Rector et al., 2009). Importantly, local differences in sleep depth do not seem to be random. Local increases in slow wave activity in sleep may be triggered by learning tasks performed before sleep that are known to activate specific regions; local changes in sleep also correlate with improved performance on memory and learning tasks after sleep (Huber et al., 2004). There is much evidence on how different sleep stages support different kinds of memory processing (Rasch & Born, 2013), but it now seems that these effects can be localized rather than distributed over the whole brain. Importantly, these local changes do not seem to be outliers, occurring only in particular situations (as in the first-night effect) or in transitional states or sleep disorders. Rather, they appear to be part of normal sleep regulation, and the regional, use-dependent specificity of these changes may be central to the contribution of sleep to memory and learning. Local changes also occur during sleep onset, in which slow wave activity spreads gradually from frontal-central to posterior regions (Siclari & Tononi, 2017). Regional dissociations between sleep and wake might also explain what is going wrong in sleep disorders such as insomnia (Siclari & Tononi, 2017; Castelnovo et al., 2018).

What (if anything) might local changes in sleep depth feel like? Gradual transitions during sleep onset might underlie the emergence and typical pattern of sleep onset imagery (Siclari &

Tononi, 2017). Moreover, as noted earlier, local changes in a parieto-occipital hot zone involving a reduction of slow wave activity precede reports of conscious experience following both REM and NREM awakenings, suggestion an association with dreaming (Siclari et al. 2017).

Another more speculative example comes from lucid dreaming. Research into the neural correlates of dream lucidity suggests that the realization that one is now dreaming is associated with gamma activity in the dorsolateral prefrontal area (Voss & Hobson, 2015). This area is comparatively deactivated in REM sleep, which fits in well with the relative lack of critical reasoning and metacognitive insight in nonlucid dreams (Desseilles et al., 2011). Originally, this regional change in frontal activity prompted the suggestion that lucid REM sleep is a hybrid state between sleep and wakefulness (Voss et al., 2009). However, as the phenomenology of lucid dreams is still distinctly dream-like, including bouts of ad hoc, irrational thinking as well as spontaneous contents and immersion, an alternative is to regard lucidity as a substage of REM sleep (Windt & Voss, 2018). Lucid REM sleep would then be a combination of overall REM-like activation with local wake-like activity in frontal areas. This also fits in well with the fact that many people describe the onset of lucidity as awakening within their dreams.

An important question arising from this research is whether we should move towards locally rather than globally defined sleep stages. If that idea is on the right track—and leaving methodological complications to the side—then it is no wonder the traditional paradigm of searching for a sleep stage correlate of dreaming was unsuccessful. Researchers may have failed to align conventionally defined sleep stages with changes in experience because they were looking for changes in brain activity in the wrong place—or rather, in too many places. Making sleep stages more precise might then not consist just in distinguishing more of them in ever-shorter temporal periods, but in carving them up more finely on a spatial level as well. What we now call global sleep stages might then get replaced by different combinations of locally defined sleep stages, with different relations to kinds of sleep-related experience. Conceptually and methodologically, this would require a profound revision of sleep stage scoring. It would also change how we think about sleep and wakefulness.

The result would be a conception of sleep, including sleep stages, that is multilevel, integrating phenomenological and behavioral evidence as well as spatially and temporally fine-grained measures of brain activity. On the objective side, more precise definitions of sleep staging and of sleep-related experiences are required. One option is to distinguish substages within sleep stages as currently defined, in hope of mapping these onto specific types of sleep-related experience. As in the example of substages of sleep onset, this could involve increasing

temporal resolution and distinguishing more precisely between EEG signatures. Another option, given current sleep research, is that future sleep staging will cut across sleep stages as currently defined, for example by treating sleep stages as locally driven. Because local sleep is both temporally and spatially defined, whereas conventional sleep stages are conceived of as whole-brain phenomena, this could mean that a future descendent of N3, as defined by slow wave activity, could arise within REM sleep or even wakefulness. A seemingly paradoxical outcome could be that a move towards greater precision in sleep staging might make clear-cut categorization of waking versus sleep more rather than less elusive. If parts of the brain can be asleep while the rest is awake, or if parts can exhibit slow wave activity while the rest is in REM sleep—and if this is associated with behavioral and phenomenological changes consistent with that state—questions about whether the entire creature is asleep or awake, or in one sleep stage or another, might require more nuance than a simple yes/no answers can provide.

On the subjective side, I propose that simulation views are ideally suited to this task. This is because they offer a neutral approach that defines dreaming (and dreamless sleep experiences) independently of conventionally defined sleep stages and so are ideally poised to avoid the confounds associated with current definitions. The ability of simulation views to focus on different aspects of dreaming (and dreamless sleep) means they can be rendered more precise. For example, immersive (and hence dreamful) but static experiences lacking movement sensations and narrative progression, such as quietly sitting on a bench, might be unique to certain types of NREM sleep dreams, whereas dreams at sleep onset or during REM sleep might be consistently dynamic (Nielsen, 2017; Windt, 2019). Even the transition from non-immersive and hence dreamless to immersive and hence dreamful experience might be gradual, and the spatial and temporal dimensions associated with *here* and *now* experience might come apart (Windt 2015a). Depending on the research question, it may be instructive to zoom in on some physiological and phenomenological changes, while taking a bird's eye view on others. A future framework should allow for such flexibility.

More generally, finding the right level of granularity for multilevel sleep stages might depend both on methodological and theoretical considerations. If the appropriate level of spatial and temporal resolution in sleep staging, as well as phenomenological detail, were found to vary strongly across research questions, it might even make sense to move away entirely from sleep staging as we think of it today towards multiple co-existing and flexibly adaptable systems.

Future challenges and perspectives

The traditional image of sleep as a period of passivity and rest involving a global loss of behavior and subjective experience is outdated. Sleep is active and phenomenologically and behaviorally diverse; these subjective and behavioral differences are flanked by differences in brain activity that increasingly seem to be local rather than global. It also seems safe to say that forms of sleep experience exist that lack the immersive structure of dreaming and hence qualify as dreamless. Especially in the deeper stages of NREM sleep, consciousness appears to wax and wane, fluctuating between dreamful and dreamless experience interspersed with blackout periods in which consciousness is lost. Neither sleep in general nor NREM sleep in particular can therefore be described as uniformly unconscious.

An important question is how findings on sleep-wake transitions, state dissociations, and local sleep, in conjunction with phenomenological considerations, change both the concepts of sleep and wakefulness and conventionally defined sleep stages. Future research will have to clarify, for example, at which point local changes—such as local intrusions of slow wave activity into REM sleep or wakefulness—change the overall state. Put differently, how should we individuate global states of sleep and waking as well as sleep stages in relation to local changes, reconciling parts of the old scoring system with the new?

And how much would a revision of the concept of sleep based on local changes upset our broader taxonomy of mental states? If sleep is locally regulated, does this imply that sleeping and waking themselves are no longer things persons or even brains do, but can be ascribed exclusively to parts of brains—and possibly even different parts at different times? How can we reconcile this idea with the continued need for saying, if only for practical reasons, that at a given time, a person is awake or asleep, conscious or unconscious?

And moving beyond sleep: Do we need a wake-stage architecture and scoring systems for wake stages, similar to what we now have and/or will develop for sleep? And might local sleep in wakefulness map onto "dream"-like mentation, as in particularly vivid instances of waking mind wandering or daydreaming (Andrillon et al., 2019)?

Even more generally, can we make sense of local changes in experience – local consciousness – and not just local brain states? At least in some cases, what looks like a mereological fallacy of misattributing states of whole persons to their parts (Bennett & Hacker, 2003) might turn out to be an informative research strategy.

These questions raise deeper matters about how finely to carve up our ontology of the behavioral states of sleep and wake, but also of background or global states (or modes) of

consciousness such as dreaming and other altered states. How many such states exist, and is their existence a matter of drawing deep metaphysical distinctions, or rather of introducing standardized nomenclature to facilitate mutual understanding among different research groups? Can we arrive at such categories through a top-down approach employing familiar folk-psychological categories and conceptual analysis, through a bottom-up approach driven by large-scale neuroscientific databases, or something in between? Or might we even strive towards different ontologies, depending on the context (e.g. distinguishing one set of states for the science of sleep and consciousness and another for sleep medicine)?

These questions bear similarity to the cognitive ontology debate (Bluhm, 2017; Janssen et al., 2017; Poldrack & Yarkoni, 2016); yet while that debate focuses on cognitive processes such as working memory that can be isolated through use of specific experimental tasks, such a task-based approach has limited applicability to sleep-related experiences (Bernardi & Siclari, 2019). Establishing a framework for sleep-related experiences including sleep stages is part of what we might call a *conscious state ontology* and raises methodological challenges of its own.

This brings me back to my main point: only when we survey sleep-related changes in behavior and brain activity together with associated changes in subjective experience do the full consequences of recent empirical findings and theoretical advances for the concepts of sleep and wakefulness become apparent. How to reconcile developments in sleep and dream research with how we think about our mental states is deeply challenging; yet working towards an integrated account holds genuine promise and allows us to consider not just sleep, but also waking and consciousness themselves from novel vantage points. Here I hope to have given an overview of ways in which research findings have already challenged our understanding of the mind during waking and sleep, as well as a preview of things to come.

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