RBD: A Window into the Dreaming Process

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17.1 Introduction

Rapid eye movement sleep behavior disorder (RBD) is often defined as dream-enacting behaviors. However, more attention has been paid to the motor aspects (because of risk of injuries) and to RBD as a preclinical sign of neurodegeneration than to its dreaming aspects. Notably, the first RBD animal model, developed in cats as early as in the 1960s by the Jouvet group in Lyon, France, was named "oneiric behavior," because these animals displayed apparent dream-related behaviors (leaping, chasing, and fighting) during REM sleep [1]. Note that "oneiric" is the Greek-origin term designating dream aspects. The model was even used to determine "what does a cat dream about?" illustrating how much these pioneers believed in the dream-action hypothesis [2, 3].

We would like to develop here in depth the dreaming aspects of RBD and what insight RBD has brought to the domain of cognition during sleep. RBD constitutes a unique window to study the dreaming process from a point of view external to the dreamer. Indeed, behaviors, facial expressions, and verbal utterances are in accordance with the dream reports obtained upon awakening. This condition (named isomorphism) brings strong, unbiased evidence that dreaming occurs during sleep and is not built upon awakening or reconstructed afterward by the sleeper to please the investigator/clinician. One fascinating aspect of RBD is that the observer has, for the first time, the feeling of seeing "solid" mental images. Plus, RBD allows the study of whether eye movements follow dreaming imagery, whether non-dreamers do not dream or do not recall dreams, and whether motor or verbal learning is overtly replayed within dreams. Eventually, the directory of all behaviors, speech,

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C. H. Schenck et al. (eds.), *Rapid-Eye-Movement Sleep Behavior Disorder*,
https://doi.org/10.1007/978-3-319-90152-7_17

and facial expressions during RBD will constitute a fascinating ethology of the dreaming process.

The first part of this chapter is devoted to the dream content during RBD, how much it is recalled, how it may differ from "normal" dreaming (in idiopathic RBD as well as in Parkinson's disease-associated RBD), and how RBD behaviors may correlate to dream recall (including the current debate about whether dreams evoke behaviors or behaviors evoke dreams and whether the content is systematically active/violent or not). The second part is devoted to how to use RBD as a (small) window to overtly approach the physiology of dreaming and cognitive processes during REM sleep. It includes how RBD can be used to demonstrate if non-dreamers do actually dream and if eye movements are tightly coordinated with the general behavior including dream images during REM sleep, to test the replay hypothesis for sleep-related verbal and motor memory consolidation and to study the phonetics and semantics of language during sleep.

17.2 Characteristics of Dream Content During RBD

The observed vocalizations or behaviors during RBD often correlate with simultaneously occurring dream mentation, leading to the frequent report of "acting out one's dreams." The behaviors usually manifest as attempted enactments of unpleasant, action-filled, and violent dreams or nightmares in which the individual is being confronted, attacked, or chased by unfamiliar people or animals. Typically, at the end of an episode, the individual awakens quickly, becomes rapidly alert, and reports a dream with a coherent story. The dream action corresponds closely to the observed sleep behaviors. We will examine the evidence supporting the presence of dreams upon awakening from an RBD episode, the evidence supporting the concordance between the action in dreams and in reality, and the evidence for/against predominance of violence in RBD dreams.

17.2.1 Dream Recall upon Awakening from REM Sleep Behavior Disorder

The recall of a dream upon awakening from REM sleep in normal subjects is frequent but not systematic, as 20–23% of REM sleep awakening do not elicit any dream recall [4–6]. Similarly, if most patients report a dream upon awakening from an RBD episode, this is not a universal finding. Sixty-four patients with RBD and Parkinson's disease were interviewed with a systematic questionnaire in Italy [7]. Spontaneous awakenings from the RBD were reported as often or always in 40.3%, sometimes in 22.6%, and never in 35.5% patients. Among them, 66.1% were always/often readily awoken, whereas it was only sometimes the case in 19.4% and never the case in 3.2%. The orientation upon awakening was frequently good in most (88.7%) patients, but occasional in 4.8% and absent in 1.6%. Dream content recall upon awakening was often present in 59.7% of

patients, sometimes in 33.9%, and never in 1.6%. In 122 patients with idiopathic RBD in Barcelona, 93% recalled some unpleasant dreams, but 7% had no recall of abnormal dreams [8].

17.2.2 Dream-Behavior Isomorphism

Because patients who are awakened immediately after a behavioral episode during RBD frequently report a dream content that is congruent with the objective behavior observed prior to awakening, these behaviors are believed to represent the acting out of dreams while sound asleep and unaware of one's surrounding. The concordance between the dream actions (reported upon awakening from these behaviors) and the behaviors observed by the bed sharer or by clinicians on the video-monitoring during proven REM sleep in the sleep lab is called isomorphism. The existence of a dream-action isomorphism has been supported in numerous case reports by history and by direct observation in the sleep laboratory (Table 17.1). It has been tested in a single controlled study and debated in the context of the analysis of REM sleep-associated twitches in developing rats.

Table 17.1 Dreaming characteristics in patients with RBD

Characteristics/population	Results	References
Dream recall upon awakening from a motor RBD event		
Interview of 64 PD patients with RBD	66% readily awoken; dream recall often present in 59.7%	[7]
Unpleasant dreams upon awakening from a motor RBD event		
Interview of 64 PD patients with RBD	91% of RBD dreams include fighting in response to danger	[7]
Dreams they remember in the last month, in 41 patients with RBD vs. 35 controls	More aggression and animals in patients' than controls' dreams	[21]
Interview of 122 patients with idiopathic RBD	93% recall unpleasant dreams, 7% recall normal dreams	[8]
Possibility of pleasant dreaming activity during enacted dreams		
Interview and sleep monitoring in a clinical sample	18% of patients with Parkinson's disease enacted both pleasant and unpleasant dreams; numerous examples of nonviolent dreams and behaviors in patients with RBD	[12]
Dreaming/motor activity isomorphism		
Incidental reports by spouses	Clear dream/action concordance	[9–14]
Incidental observations on video-polysomnography	Scenic RBD behaviors followed by congruent dream recall	[12]
Blind matching of four possible/different dream reports with one videotaped RBD motor behavior in (each of) six patients with RBD	The matching was 33%, above the 25% random matching rate	[15]

17.2.2.1 Home Reports

There have been many incidental reports of clear dream-action isomorphism in RBD [9–14]. As clinicians, we are fond of such stories, because they are important for the diagnosis of the disorder, and unravel all the beauty of the dreaming life, even when dreamt events are rather nightmarish. In our series of 53 patients with Parkinson's disease and RBD, patients and spouses revealed several examples of perfect dream-action isomorphisms [11]. A patient dreamt that he was a police duck, flying after a pigeon thief; in real life, his wife observed him squatting on the bed, waving his arms as if flying, and shouting "pin pon" (the two-tone sound of a siren) with a duck's voice. Another man dreamt that he was in a canoe, attacked by caimans, trying to make them flee. In reality, he was sitting on the bed rowing without paddles, shouting "Help, caimans!", getting hold of a heavy oak bedside table, and throwing it across the room. Another patient dreamt he was a knight fighting with a sword to save his endangered ladylove; in reality, he was lying in his bed, fighting with an invisible sword, with great agility and shouting "Manon, Charlemagne!" (a medieval battle cry). In 222 patients with idiopathic RBD in Barcelona, some examples of isomorphism are given [14]. A male, aged 65, roared loudly and woke up, recalling a dream where lions were attacking him. A 63-year-old man dreamt that someone was chasing him to the point that he jumped in a river to escape; instead, he jumped out of his bed. A 64-year-old woman dreamt that someone puts a straitjacket on her; in real life, she struggled to take off her pajamas while kicking. A 63-year-old man dreamt that a dog was attacking him; asleep in his bed, he said: "a dog wants to eat me" (note the excellent isomorphism here, provided by the concordant sleep talking). In *Paradox Lost* Carlos Schenck reported on a man who hit his head against the wall, later recalling he was fighting against a mean dog [10].

17.2.2.2 Reports of Behaviors Concordant with Dream Recall During Video-Polysomnography

Apart from the history, an excellent matching between behaviors and further dream recall was observed in several cases [12]: a retired carpenter with narcolepsy was studied in the sleep lab and reported after awakening of having drawn and then built a stair with a plank in a dream. During the corresponding REM sleep episode, he shook an invisible hand, while he introduced himself as "I am Mr. Do." Later, he seemed to draw while whistling, to measure, pull, to his tools and then hit something with a fictive hammer for almost 10 min. A patient with idiopathic RBD dreamt of meeting a minister. The minister told him: "What? You do not salute an old friend like me." So he shaked his hand. In the corresponding REM sleep episode, you can see him sitting in bed and shaking an invisible hand while saying "Good day!" Only the end and active part of the dream scenario was enacted out in this case. A patient with Parkinson's disease reported a long dream in which he was a knight in the medieval time, riding his horse around France for a whole day. Then he rested in a small inn, sleeping on the hay on the floor, as a Saracen fighter entered the room through the window and threatened to kill him with a scimitar. The knight could not grab his sword but found in the hay a wheat flail and defended himself

Fig. 17.1 Representation of the isomorphism between an RBD behavior and the concomitant dream (Artist: Cléa Arnulf, based on the video clip and report of the patient). This patient recalled a long medieval dream during which he was defending himself with a wheat flail against a Saracen fighter attacking him with a scimitar. Instead, in the actual bedroom, he was handling the tubing of his positive airway pressure device to defend himself

with it. In the corresponding video-polysomnography, the patient, lying on his back and sometimes sitting in bed, fought firmly back at an invisible aggressor, and placed on his right hand, using his fist on the positive airway pressure tubing (Fig. 17.1). All these cases of scenic behaviors illustrate an excellent dream-behavior correspondence, at least for some parts of the dream scenario. However, one may notice that despite the recalled dreams being often long, the observed behaviors were short, possibly acting out only a (final?) part of the dreamer's dream mentation.

17.2.2.3 Formal Testing of the Dream-Behavior Correspondence

The congruence between the actual action performed by RBD patients during REM sleep and the dream content later recalled has been formally assessed in a single study [15]. Seven blind judges had to match a set of four possible dream contents (collected upon serial awakenings after 10 min of REM sleep in the second and successive episodes, in patients with Parkinson's disease, with and without RBD), of which just one of the dream contents was correct, with motor behaviors videotaped during REM sleep in six patients with RBD. The possibility to match adequately one of these dreams by chance was 25%, as there were four choices. Of the 35 REM sleep awakenings performed, a total of 17 (48.6%)

motor-behavioral episodes with recalled dream content were obtained. The average of correctly identified video-dream pairs was 39.5% (range 0–100%), which is significantly above the chance level, but still in less than half of episodes. One may wonder why the concordance did not approach 100%. However, one should note that this video series contained mainly simple movements, which are difficult to match with any behavior, whereas scenic behaviors were rare, despite being easier to match, due to the complexity of the behaviors and vocalization observed in these cases [15]. An example of dream-behavior pair is, for the motor part on the video, "raising both arms for several seconds, then grabbing for something. Few lip movements resembling talking without sound. Intermittent small distal limb and head movements. No apparent emotion." And the corresponding dream report was **"**I was in a competition. There was a race and we had to run, and step into open tubes. Open tubes floating in a lake. We had to get there. We had to run to the tubes, then jump into them and then paddle to the other side of the lake. Then, on the other side, we had bicycles, and we had to ride to our homes. But there was a bridge to cross, it was bottle-like, very narrow. There was a little fight over who was the first. I tried to get to the bridge first. There was a fight for the best position. I was part of this fight. Actually, it was a lot of fun. I was pleased." This is a complex experiment in a small sample, requiring patients with RBD to accept being awakened three times per night and report immediate dream recall. So far, it has not been reproduced.

17.2.2.4 Dreams Evoking Behaviors or Behaviors Evoking Dreams?

The RBD-associated behaviors are often thought to result from a dysfunction involving atonia-producing neural circuitry in the brainstem, thereby unmasking cortically generated dreams, exactly as if a curtain was placed in front of a theatrical play (normal, atonic condition) or instead raised up (RBD condition). This view may however be too simplistic. It is challenged by two conditions: REM sleep with enhanced chin (postural) muscle tone but without RBD (remembering a raised curtain without any theatrical play behind it) in some patients and by phasic movements despite preserved chin atonia (a theatrical play made visible through the atonia curtain), presumably indicating that over-activation of the phasic motor system has overwhelmed REM atonia. If the loss of atonia is an admitted fact, the "dreaming" and cortical origin of behaviors in RBD is still a debate among scientists. On the one hand, numerous complex behaviors (including speech and learned behaviors, e.g., smoking, dealing cards, lecturing) can be observed during RBD [16]. These are not archaic behaviors and could not result from a source other than the motor cortex.

On the other hand, the group of Blumberg (Iowa, USA) has suggested another source apart from the motor cortex for the RBD behaviors, based on studying the central drive of muscle twitches during REM sleep in newborn rats [17]. Early studies in animals showed that REM sleep twitches were not driven by the motor cortex, because they persisted even when the brain areas located above the peduncle were removed or disconnected from the brainstem, indicating that the generator of twitches was located between the medulla oblongata and the superior colliculus

[18]. Later, Blumberg et al. showed that the cortical motor activity increased during REM sleep, but it did so immediately after (and not immediately before) twitches. Because the latencies from twitches to peak neural activation were greater than 100 ms, their conclusion was that the sensory feedback (i.e., re-afference) from twitching limbs was driving activity in motor cortex [19]. Notably, during wakeful movements, the nervous system drives movements and simultaneously generates a copy of the motor command (the corollary discharge) to inform the sensory cortex of the expected changes. This process helps to distinguish sensations that are self-generated from those that are external. By contrast, during REM sleep the twitches are not accompanied by corollary discharges, and "surprise" the sensory cortex, and also trigger strong activity in the primary motor cortex that is not seen in response to passive movements of the tail when awake [19]. These twitches might contribute to an activity-dependent development of the spinal cord, cerebellum, and forebrain and to the construction of internal models.

Moreover, several authors mentioned that, in animals, the motor cortex is not even necessary to produce complex behavior; for example, chemical and electrical stimulation of some brainstem structures can produce defensive and aggressive behaviors in rats and monkeys that may resemble those reported in human patients with RBD. Accordingly, Mark Blumberg suggested that the brainstem (and possibly the red nucleus) could be one of the sources of the pathological movements and that sensory feedback from moving limbs could secondarily influence the content of dream mentation [17]. This reverse hypothesis, which is not incompatible with the previous, "descending" hypothesis (behaviors are the products of dreaming), suggests that a brainstem motor pattern generator of either simple movements (myoclonic twitches) or patterned behaviors (e.g., defense, attack) would first evoke movements, which in turn, via sensory feedback, would evoke dreams incorporating these stimuli.

17.2.3 Violent Dreams

17.2.3.1 A Predominance of Fighting Behaviors

Most descriptions emphasize the forceful and violent aspect of the RBD-associated motor behaviors (Table 17.1), which are usually associated with vivid, unpleasant, and active dreams [20]. The dreams associated with RBD are usually different from those experienced by patients before RBD onset, although this assertion is difficult to prove, as none completed a dream diary prior to RBD onset. The patients report enacted dreams containing more elements of aggression and animals than control subjects when they are asked about the dreams they remember in the last month [21]. In 58 patients with Parkinson's disease plus RBD, the most commonly associated dream is fighting in response to danger (91%), whereas pleasant activity is reported in 20% of patients and daily activity in 22% of patients [7]. In 188 patients with idiopathic RBD recalling unpleasant dreams [14], the following contents were reported: attacked by someone (76.8%), arguing with someone (63.5%), chased by someone (55.7%), falling from a cliff (47.8%), and attacked by an animal (39.9%, involving, in descending order of frequency, dogs, snakes, lions, bulls, horses,

insects, cats, rats, tigers, pigs, wolves, crocodiles, cows, moles, piranhas, wild boars). Dreams containing children in danger were reported by 12.8% of patients. In a group of 66 patients with Parkinson's disease and RBD, all reported they had at least once some violent behaviors [12].

17.2.3.2 Threat Simulation Theory: Fight vs. Flight?

A mechanism of this violence during RBD could be related to a general function of dreams, as suggested by the threat simulation theory [22]. This theory suggests that the function of dreaming is to simulate threatening events in a virtual environment and to rehearse threat perception and threat avoidance for the evolutionary purpose of increased survival. These dreams of fighting wild animals and aggressors are not a consequence of personality changes, as they contrast with the placid personality and absence of aggressiveness during the daytime in RBD patients [13, 21]. Whether the threat simulation theory applies to RBD dreams (vs. sleepwalking/sleep terrors) was studied in a group of 24 subjects with RBD vs. 32 subjects with sleepwalking or sleep terrors [13]. Subjects completed aggression, depression, and anxiety questionnaires. The mentations associated with sleepwalking and RBD behaviors were collected over their lifetime (as far back in time as they could remember) and on the morning after video-polysomnography. The reports were analyzed for complexity, length, content, setting, bizarreness, and threat [23, 24]. Almost all of the sleepwalkers and patients with RBD reported enacted dreams. The enacted dreams of subjects with RBD were more complex and less bizarre than the dreams of sleepwalkers (who had more discontinuous mentations), but the dreams were similar in length in both groups when dreams were reported over their lifetime. Aggression was more frequently observed during the RBD-enacted dreams than during sleepwalking. Up to 70% of sleepwalking dreams and 60% of RBD dreams involved a threat. There were more misfortunes and disasters in the sleepwalkers' dreams, and there was more aggression in the RBD dreams.

The response to these difficulties differed between the groups, as the sleepwalkers mostly fled from a disaster, while most (75%) patients with RBD counterattacked when assaulted. These major differences in the type of threat and in the dreamer's response were reminiscent of the fight-or-flight response to threats. Subjects with RBD defended themselves, and less frequently their family from attackers (mostly human strangers), and rarely were the first attacker in the dreamt fight (6%). The RBD-enacted dreams involved more aggression when retrospectively collected over a lifetime span than when prospectively collected on the morning following the sleep monitoring, suggesting a recall bias (dream recall likely is enhanced when the dream-enacted behaviors lead to an awakening or injuries, which more frequently occurs when the dream content is violent). In the dreams of normal healthy subjects, aggressive behaviors are twice as frequent (65%) during REM sleep compared to NREM sleep. Therefore, RBD-associated aggression may be a disorder of enacting dreams (aggression dreams because aggression is frequent in REM sleep dreams) rather than a disorder of dreaming. Alternatively, these threats in RBD may be the exacerbation of systems that train humans to appropriately react during the daytime to a wide spectrum of dangers.

17.2.4 Nonviolent Dreams

Some dream-enacted behaviors can be prolonged and scenic. They include gesturing, reaching, grabbing, arm flailing, slapping, punching, kicking, sitting up, and leaping from bed. Nonviolent elaborate behaviors, however, occur in 18% of patients with Parkinson's disease and RBD (coexisting in this case with violent behaviors within the same or other nights), as well as in patients with idiopathic RBD and RBD associated with other diseases [12]. They include eating and smoking (fictive behaviors in the absence of real food or cigarettes); picking apples; dancing; teaching; gesturing thumbs-up; kissing; giving a lecture; selling textiles; clapping at a show; sorting buttons; displaying pelvic, coitus-like thrusting; masturbating; urinating (while dreaming of urinating in a river as a child); scoring a goal; bicycling; greeting; flying; building a staircase; getting dressed and inspecting the army; and searching for treasure. Most behaviors are learned behaviors in accordance with the cultural and social context of the patient. Patients display various types of vocalizations, such as mumbling, talking, shouting, swearing profanities, laughing, and crying [20]. However, the majority of patients mumble or speak during RBD, sometimes quite easily, and they speak with appropriate prosody, gestures, fluency, and syntax [12]. Singing and whistling are possible with correct musicality, and the local dialect is maintained [12].

The Barcelona team looked at occasional nonviolent elaborated activities reported by the spouses of 203 patients with idiopathic RBD: action-filled sports were present in 15.8% of RBD dream content, including soccer (81.3%), then boxing (6.3%), and skiing, basketball, motorcycling, and cycling (3.1% each). Love (kissing in three cases), giving a political speech (three cases), teaching a lesson (one case), shuffling, picking things, and riding were also reported [14]. In one patient, a behavior resembling sexual intercourse with an imaginary partner and accompanied by a disgusting comment occurred on a single night, as reported by his wife. Patients who experienced these nonviolent behaviors also displayed aggressive behaviors during the same or different nights.

This possible enactment of nonviolent dreams is also observed in patients with Parkinson's disease, with or without RBD [25]. When dream reports are collected daily over several weeks in patients with treated RBD and controls, there are no differences in the content of the dreams, suggesting either a bias of recall shifted toward selectively remembering the enacted violent dreams or a benefit of clonazepam on the abnormal dreaming process itself [26]. Furthermore, when 69 dream reports are systematically collected upon provoked awakening from NREM and REM sleep in patients with Parkinson's disease with (n = 9, mostly during RBD movements and sometimes during quiet REM sleep) and without (n = 6) RBD and analyzed for content, action-filledness (actions, environmental events), vividness (cognition, emotions), intensity, and threatening elements (including aggression) are not different between groups, although emotions are more negatively toned in those with than without RBD [27]. Further, patients with RBD tend to act out their most intense dreams, and negative dreams may more likely be acted out than positive dreams [15]. Consequently, the acted out dreams are the ones most likely to be

remembered afterward. The retrospective memory bias for intense and aggressive dreams may thus reflect these infrequent tip-of-the-iceberg dreams (and not be a bias after all), although the majority of dreams of patients with RBD are not altered in any way. This interesting study supports the idea that the dream content is similar in patients who enact or not their dreams, presumably suggesting that there is no change in dream content in Parkinson's disease with RBD but a change in muscle atonia network.

17.2.5 A Change in Dreaming Caused by Parkinson's Disease?

Compared to normal controls, the dreaming activity changes in Parkinson's disease. As many as 46% of patients report altered dream phenomena, including a high frequency of nightmares and violent or unpleasant dreams, especially when levodopa therapy is introduced [28–31]. Cipolli et al. examined the narrative quality of dream experience in 13 patients with Parkinson's disease after provoked awakenings from REM sleep. Patients had a dream recall frequency (71.9%) in REM sleep within normative ranges. Plus, the length of a dream as a story paralleled their cognitive level (score in the Mini-Mental State Evaluation), but not their age, disease course, or dose of levodopa. The organization of dream contents into coherent episodes paralleled their language comprehension (Token test) [32]. In early Parkinson's disease stages, patients' dreams differ from those of the control group in features related to aggressive actions (in which they frequently had a passive role), the presence of animals, a relatively higher frequency of friendly acts toward other characters, and a lower frequency of bodily misfortunes [33]. As the altered dreaming correlated with frontal cognitive impairment and not with the presence or absence of concomitant RBD, the authors speculate that the higher level of aggression reflects intensification of the limbic preponderance during sleep due to a loss of the prefrontal regulatory influence. In contrast, Borek et al. found a relatively higher frequency of aggressive features in patients with Parkinson's disease, with vs. without RBD (with no further difference in men vs. women with RBD), although dreams were less aggressive in women than in men [25].

The altered dreaming activity was associated with more frequent awakenings and illusions/hallucinations, but not with specific (levodopa, dopamine agonist) medications [30]. A "kindling" phenomenon, starting from altered dreaming and evolving toward illusions, hallucinations of minor then major severity, and eventually psychosis, was suspected at that time [28]. However, the presence of vivid dreams/nightmares correlated with concurrent hallucinations, but did not predict the future development of hallucinations when they occurred in non-hallucinators in a 10-year prospective study [34]. This interest toward vivid dreams and nightmares as a first step toward hallucinations and psychosis did not include the concept of RBD, which was not yet identified as a disorder at this time [28]. When RBD was later examined at entry in the cohorts, it proved to be a major determinant for concurrent and incident hallucinations, as well as the later development of psychosis and

dementia [34, 35]. More recently, the presence of RBD in 80 dementia-free patients with PD for a mean 5.7 years was the highest (odds ratio, 49.7) risk factor for developing dementia within the 4 next years, much higher than classical risk factors such as cognitive impairment or age [36]. Illusions and hallucinations were also predictors of dementia, with odds ratios of 8 and 10 [36]. It was not specified, however, whether RBD was a predictor of hallucinations and psychosis in this group of patients.

17.2.6 Are RBD Dreams Occurring During Genuine REM Sleep?

Because visually elaborate dreams are closely associated with normal REM sleep, the report of complex dreams, congruent with the observed sleep behavior, in patients awakened from an RBD episode constitutes convincing evidence that RBD is a manifestation of normal REM sleep (apart from the motor dyscontrol). Furthermore, most patients with RBD have no reflexive consciousness when they exhibit movements during the RBD episodes, as illustrated by a 74-year-old patient with narcolepsy, monitored while his wife was present in the room [37]. During an RBD episode, he whistled and seemed to draw and take measures (he dreamt that he was building a stair). His wife, thinking that he was awake and eager to be unhooked from the electrodes, told him not to move and to wait for the nurse. The patient needed several seconds before reacting; then he woke up and answered "What?" [she repeated her remark] "I did not say anything, I was sleeping." His wife concluded: "Oh, just I thought… So you were dreaming!" Thus, the patient was able to qualify his previous state as sleep and his present state as awake, strongly suggesting that RBD is a within-sleep-state phenomenon. In the same study, a patient was snoring during RBD behaviors, another had a penile erection (associated with a fighting behavior), and another one had loss of reflexive consciousness during the motor episodes. Taken together, these respiratory, cognitive, and autonomic clues support the concept that RBD occurs within genuine REM sleep and does not emerge from it. If this assumption is right, RBD (and its overt motor, autonomic, and cognitive features) could be used as an original model to study some mechanisms of normal REM sleep. For example, the penile erection associated here with overt fighting in RBD provides additional evidence that REM sleep-associated penile erection is an autonomic automatism unrelated to sexual dreams.

17.3 RBD as a Model to Shed Light on the Dreaming and Cognition Processes During Sleep

The congruence between dream enactment and concomitant dream content during RBD behaviors is a potent tool to test various hypotheses about dreaming and cognitive (e.g., memory, language) processes using the objective measures of REM sleep-associated behaviors, mimics, and vocalizations (Table 17.2).

Table 17.2 Contribution of RBD studies to the study of cognition and dreaming processes during REM sleep

Domain	Findings	References
Dream recall from REM sleep in non-dreamers	Non-dreamers exhibiting complex RBD were described, supporting the hypothesis that non-dreamers do dream, but do not recall dreams	[45]
Eye movements in association with dreaming images	Patients with goal-directed behaviors during RBD had eye movements directed to the target of their behavior and dream images, suggesting eye movements, behaviors, and dream images are co-organized by the sleeping brain	[47]
Procedural memory and consolidation during sleep	A recently learned motor sequence was partially replayed during a sleepwalking episode but not during RBD episodes	[55]
Verbal memory and consolidation during sleep	A recently learned verbal story was partly replayed with maintained meaning during REM sleep	[56]
Language	Language during REM sleep is grammatically correct. Verbal abuse outnumbers polite language	[58]

17.3.1 RBD as a Model to Support That Non-dreamers Do Dream

17.3.1.1 The Enigma of Non-dreamers

Dreaming is defined as mental activity during sleep [38]. It has long been solely accessible by the recollection of the dreamer after awakening. However, the frequency of dream recall varies considerably among individuals and within one individual from night to night, as well as with the method used to measure dream recall. Adults report, on average, 1–2.8 dream recalls per week in a dream questionnaire [39, 40] and 2.38 dream recalls per week when a home dream diary is completed [41], whereas there are substantially higher recall rates (77–90%) following REM sleep awakenings and also following NREM sleep awakenings (50–74%) in a sleep laboratory [4, 42].

Non-dreamers occupy an extreme end in this spectrum of individual differences in dream recall frequency. The incidence of adults who report on a questionnaire that they never dream varies from 2.7 to 6.5% [43, 44]. However, when questioned by phone, most of the same individuals report that they had an experience of dreaming (previously as an adult or child), which leads to an estimate of 0.38% of a clinical sample of adults who have never ever experienced any type of dreaming [44]. When awakened at the end of REM sleep periods in a sleep laboratory, the same non-dreamers did not report any dreams, even when a broad definition of dreaming was used that included thoughts, feelings, and emotions [44]. This group of individuals does not differ, based on polysomnography, clinical or demographic variables, from a comparable group of low dreamers that occasionally reports dreams when awakened in a sleep laboratory. This finding demonstrates that dreaming may not be a universal experience. Whether these non-dreamers either have no dream production or do have recall that could not be tested because there is no reliable marker of dreaming activity to be contrasted with dream recall remains an open question. These fascinating experiments regarding dream recall postulate that

dreams are not directly accessible. Consequently, the study of dreaming has been restricted to the analysis of recalled sleep mentation after spontaneous or provoked awakenings. However, this limitation may be circumvented by the discovery of RBD. Because patients awakened immediately after a behavior during RBD frequently report a dream content that is congruent with the objective behavior observed prior to awakening, these behaviors are believed to represent the acting out of dreams while sound asleep and unaware of one's surrounding.

17.3.1.2 Non-dreamers with RBD Exist and Do Enact Dreams

To determine whether non-dreamers do not produce dreams or do not recall them, we identified subjects with no dream recall and with dreamlike behaviors during RBD [45]. All consecutive patients with idiopathic RBD or RBD associated with Parkinson's disease who underwent a video-polysomnography were interviewed regarding the presence or absence of dream recall, retrospectively or upon spontaneous arousals. The patients with no dream recall for at least 10 years and never-ever dreamers were compared with dreamers with RBD regarding their clinical, cognitive, and sleep features. Of the 289 patients with RBD, eight (2.8%) patients had no dream recall, including four patients who had never-ever recalled dreams and four patients who had no dream recall for 10–56 years. All these non-dreamers exhibited, daily or almost nightly, several complex, scenic, and dreamlike behaviors and speech, which were also observed during REM sleep on video-polysomnography (e.g., arguing, fighting, and speaking). They did not recall a dream following sudden awakenings from REM sleep. These 8 non-dreamers with complex behaviors during RBD did not differ in terms of cognitive, clinical, treatment or sleep measures from 17 dreamers with RBD matched for age, sex, and disease.

The scenic dreamlike behaviors reported and observed during REM sleep in the rare non-dreamers with RBD (even in the never-ever dreamers) provide strong evidence that non-dreamers produce dreams, but do not recall them. Therefore, RBD provides a new model to evaluate cognitive processing during dreaming (and its enactment) and subsequent recall. Here is the paradox of RBD: dreams are thought to represent personal experiences; however, in the case of scenic behaviors and complex speeches, an external observer can sometimes know or guess part of the sleep mentation of the dreamers instead of the dreamers themselves (at least when they have forgotten everything following awakening). Naturally, the observer cannot see the images or hear the sounds experienced by the dreamer; however, he has privileged visual and auditory access to at least part of the scene played (and mimicked) by the dreamers.

Thus, RBD-associated behaviors may be considered materialized mental images of which some parts (the motor, facial expression and verbal parts) are made visible to the external observer, while they may not be encoded or recalled by the dreamer. RBD is a unique condition because there are no other conditions in which one may know instead of others what they are thinking and experiencing. This condition may question the very definition of dreams: if dreams are mental contents that occur during sleep and are recalled following awakening, then can RBD behaviors without dream recall be classified as dream-enacting behavior (or apparently dream-enacting behavior)? At this point, it would be fascinating to compare the functional brain

imaging of a patient with RBD during behaviors associated and not associated with dream recall following subsequent awakening. This study would help to determine the brain substrates of encoding during dreaming and subsequent recall.

17.3.2 RBD as a Model to Determine Whether the Eye Movements Scan Dream Images During REM Sleep

Rapid eye movements (REMs) and complex visual dreams are salient features of human REM sleep. However, it remains to be elucidated whether the eyes scan dream images, despite studies that have retrospectively compared the direction of REMs to the dream recall recorded after having awakened the sleeper. Determining the correspondence between eye movements and dream imagery is challenging due to the use of varying and flawed methodologies, as well as amnesia and a lack of clarity in dream recall. Furthermore, in the awake state, the eyes and head work in concert to produce gaze [46]. Only with the summation of head and eye activity does an isomorphism between gaze and target become apparent. In normal REM sleep, atonia spares the extraocular muscles but not the neck muscles so that the head cannot move, rendering the parallel between observed eye movements and the subject's description of gaze (in the dream) uncertain.

One way to circumscribe these methodological problems (recall bias, retrograde assessment, neck-eye movement combination) in humans was to study subjects with RBD (in whom the neck is not paralyzed), to determine directly whether the eyes move in the same directions as the head and limbs [47]. In 56 patients with RBD and 17 healthy matched controls, we monitored eye movements by electro-oculography in four directions (right, left, up, and down) and synchronized with video and sleep monitoring. The RBD-associated behaviors occurred two times more frequently during REM sleep with REMs than without REMs, and more often during or after REMs than before REMs, a result previously observed by the Innsbruck (Austria) and Pavia (Italy) teams [48, 49]. The density, index, and complexity of REMs were similar in patients with RBD and controls. When REMs accompanied goal-oriented motor behavior during RBD (e.g., grabbing a fictive object, hand greetings, climbing a ladder, sending a kiss with the hand), which happened in 19 sequences, 82% were directed toward the action of the patient (same plane and direction). When restricted to the determinant REMs, the concordance increased to 90%. Rapid eye movements were absent in 38–42% of behaviors. This directional coherence among limb, head, and eye movements during RBD suggests that, when present, REMs imitate the scanning of the dream scene. Since the REMs are similar in subjects with and without RBD, this concordance can be extended to normal REM sleep. However, these results do not mean that the dreamer actually watches the dream images in RBD. Rather, one common system may simultaneously activate dream images as well as eye and body movements in a coherent fashion [50]. This scenario would support the results from several experiments, including the presence of REMs in the absence of any kind of vision (in neonates,

congenitally blind humans, cats without visual cortex, pontine cats), as well as the temporal association between ponto-geniculo-occipital spikes and REMs in cats.

17.3.3 RBD as a Model to Test the Replay Hypothesis for Sleep-Related Memory Consolidation

17.3.3.1 Sleep and Memory Consolidation

It is well established that sleep facilitates plastic changes that underlie the consolidation of recently acquired knowledge. The prevailing hypothesis states that the neural traces coding for the newly acquired information are reactivated during sleep, thus fostering memory consolidation. In rats and birds, specific patterns of neural activity associated with recent waking behavior are spontaneously replayed during subsequent sleep [51, 52]. Similarly, functional neuroimaging studies in humans have shown that brain regions involved in motor skill learning are reactivated during post-training sleep [53]. Dreams also contain a high proportion of recent waking experiences [54]. However, direct evidence for a replay of temporally structured information during human sleep is still lacking. We used the RBD and the NREM parasomnia models as a way to directly observe mental content during sleep and whether it incorporated recent memories. At the time of these studies, it was suggested that procedural memory was trained during REM sleep, whereas verbal memory was trained during NREM sleep. Amazingly (you never find what you expect), the contrary was observed in our experiments: a kind of verbal replay was observed during RBD, whereas a partial motor replay was observed during NREM parasomnias, as described below.

17.3.3.2 Is There Any Reenactment of a Recently Learned Motor Task During RBD?

In a motor study, 20 patients with RBD and 19 sleepwalkers were trained on a modified version of a serial reaction time task, which is known to robustly benefit from sleep [55]. We examined whether, during video sleep recordings, the patients would replay fragments of a recently trained sequence involving large arm movements. Both patient groups showed learning of the intensively trained motor sequence after sleep. However, a sleepwalker reenacted a fragment of the recently trained motor behavior during one sleepwalking episode: she raised both arms in the premotor posture and then gently pressed on a fictive button, as during the awakened motor task. The patients with RBD exhibited several complex behaviors during REM sleep on the two experimental nights (i.e., hand movements, defense posture, kicking, punching, reaching, smiling, pointing, leaping out of bed, whispering, and speaking). No obvious motor replay of the task was identified among these REM sleep-associated behaviors. Actually, the probability of observing overt behaviors in patients with RBD and in sleepwalkers is low, making this finding of overt replay highly remarkable. Indeed, patients with RBD exhibit complex, purposeful behaviors during only 0.1–20% of the total time spent in REM sleep [55].

17.3.3.3 Is There Any Reenactment of Verbal Episodic Memory During RBD?

In this study, we aimed to determine if sleep talkers with RBD would utter during REM sleep sentences learned before sleep and to evaluate their verbal memory consolidation during sleep [56]. Eighteen patients with RBD and ten controls performed verbal memory tasks (the Free and Cued Selective Reminding Test and a 220–263 word long modified Story Recall Test) in the evening, followed by nocturnal video-polysomnography and morning recall (nighttime consolidation). They also learned a second list of words and a second story, in the morning, followed by a recall in the evening after 11 h of wakefulness (daytime consolidation). Sleep-related verbal memory consolidation was maintained in patients with RBD (+24 ± 36% words, compared a worsening during daytime consolidation) as in controls (+9 ± 18%, $p = 0.3$). Eleven patients with RBD spoke during REM sleep and pronounced a median of 20 words, which represented 0.0003% of sleep with spoken language. A single patient uttered a sentence judged to be semantically (but not literally) related to the text learned before sleep. The text to be learned was a long newspaper text about an unemployed single mother wandering about Chicago streets in 1911. She was carrying her newborn just after having giving birth, was looking for job, was unable to find one, and eventually strangled her infant. Cradling the dead child in her arms, she then carried its body several miles away and threw him in a bin. One of the patients with RBD uttered the following words during REM sleep: "Don't put me on like this…where did you wait for me? You must explain this, eh? I want an explanation now, you're a little slut because you go hanging about in the streets… and you come…I know you very well, you know?... I know you." The patient had no dream recall the next morning. This case demonstrated that the learned material was incorporated, at least, at the semantic level (a pitiful woman "slut," wandering in the street, as had the young mother of the story) during sleep talking, unbeknownst to the sleeper himself. This overt evidence provided some new insight into the creative activity of the sleeping brain.

17.3.4 Language During RBD as a Way to Access Language Processing During Sleep and Dreams

Sleep talking (also called somniloquy) is a fascinating and enigmatic phenomenon. The verbal utterances while asleep can be quite loud, ranging from simple mumbling sounds to loud shouts. Several authors noticed that most sleep speech is rare (a frequent sleep talker has to be monitored for at least four nights to obtain some verbal material) and brief and consists of a few words rather than extended remarks [57]. However, the syntax, semantics, and content of sleep speech have not been studied yet, despite the fact that human speech is a complex, high-level function in awake people.

Patients with RBD sleep talk during REM sleep, but the semantic and linguistic properties of RBD-associated language have been only recently studied [58]. In 129 patients with RBD, 75% of 548 REM sleep utterances were nonverbal, containing

mostly mumbles (40%), whispers (25%), laughs (20%), shouts (17%), lip movements without sound like a silent speech (12%), and moans (9%). Humming (2.1%) and crying (0.3%) were rare. The 211 verbal speech episodes contained a mean 8 words. The sentences were mostly affirmative (75%), but 20% were negative and 21% were interrogative. Offensive language was surprisingly frequent and outnumbered polite language. One may imagine that it parallels the dramatic and confrontational mental concerns of the dreamers (one would use verbal violence, including profanity, more readily when fighting an aggressor or when being in danger) during RBD or that it reflects some degree of social disinhibition during sleep. In this regard, a relative hypoactivity of the inferior and middle frontal cortex (which contains networks developed by education) has been demonstrated during REM sleep compared to wakefulness in functional brain imaging, possibly underlying the loss of politeness in many nocturnal speech episodes. There was a higher rate of profanities in men than in women during sleep talking, which may reflect gender differences in waking life or more physical threats in male RBD-associated dreams. Notably, nasty words were more frequent in NREM parasomnias than in REM sleep with RBD, with one third of speech episodes in NREM sleep containing profanities, and the nature of verbal offense differed between sleep stages. Verbal abuse in REM sleep with RBD lasted longer and was mostly directed toward insulting or condemning someone (with factors of intensification including more marked prosody and volume as well as repetitions), whereas undirected swearing predominated in NREM sleep. Again, these stage-related differences may reflect different mental activities, with more (aggressive) interactions with people in REM sleep in RBD, hence the insults and condemnations.

Conclusions

RBD unmasks part of the dream content, which allows studying the dreaming process in an "online" manner. To a certain degree, what is found within the unmasked material may also apply to normal REM sleep dreaming. The use of RBD to understand the cognitive processes during REM sleep is tightly dependent on the possibility to observe scenic behaviors, which are rare phenomena, compared to the number of simple, jerky movements without any clear purpose (at least for the observer) seen in the sleep lab context. There is a need for building video banks of all RBD behaviors during REM sleep, in order to share them and make progress with this line of research. Scenic RBD is a narrow, but fascinating, window upon dreaming. We think that what it may reveal from the normal (and pathologic) dreaming process is just the beginning. Let's be creative on this point!

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