Evidence that non-dreamers do dream: a REM sleep behaviour disorder model

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SUMMARY

To determine whether non-dreamers do not produce dreams or do not recall them, subjects were identified with no dream recall with dreamlike behaviours during rapid eye movement sleep behaviour disorder, which is typically characterised by dream-enacting behaviours congruent with sleep mentation. All consecutive patients with idiopathic rapid eye movement sleep behaviour disorder or rapid eye movement sleep behaviour disorder 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 recallers were compared with dream recallers with rapid eye movement sleep behaviour disorder regarding their clinical, cognitive and sleep features. Of the 289 patients with rapid eye movement sleep behaviour disorder, eight (2.8%) patients had no dream recall, including four (1.4%) patients who had never ever recalled dreams, and four patients who had no dream recall for 10–56 years. All non-recallers exhibited, daily or almost nightly, several complex, scenic and dreamlike behaviours and speeches, which were also observed during rapid eye movement sleep on video-polysomnography (arguing, fighting and speaking). They did not recall a dream following sudden awakenings from rapid eye movement sleep. These eight non-recallers with rapid eye movement sleep behaviour disorder did not differ in terms of cognition, clinical, treatment or sleep measures from the 17 dreamers with rapid eye movement sleep behaviour disorder matched for age, sex and disease. The scenic dreamlike behaviours reported and observed during rapid eye movement sleep in the rare non-recallers with rapid eye movement sleep behaviour disorder (even in the never-ever recallers) provide strong evidence that non-recallers produce dreams, but do not recall them. Rapid eye movement sleep behaviour disorder provides a new model to evaluate cognitive processing during dreaming and subsequent recall.

INTRODUCTION

Dreaming, which is defined as mental activity during sleep (Schredl *et al.*, 2003), has long been solely accessible by the recollection of the dreamer after awakening. However, the frequency of dream recall varies considerably between 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 (Nielsen, 2012; Schredl, 2008) and 2.38 dream recalls per week when a home dream diary is completed (Goodenough, 1991), whereas there are substantially higher recall rates (80–90%) following rapid eye movement (REM) awakenings and even non-REM awakenings (50–74%) in a sleep laboratory (Foulkes, 1962; Nielsen, 2000). Several factors are associated with between-individual differences in

dream recall frequency: gender (dream recall frequency is consistently higher in women compared with men in questionnaire studies); personality dimensions, such as openness to experience or related measures (boundary thinness and absorption); creativity; and the frequency of nocturnal awakenings exhibit small but significant correlations with dream recall frequency (Blagrove and Pace-Schott, 2010; Koulack and Goodenough, 1976; Nielsen, 2012; Schredl and Reinhard, 2008; Schredl *et al.*, 2003). Other factors, such as trait repression, extraversion, sleep duration and visual memory, have yielded mixed results (Blagrove and Pace-Schott, 2010). Recently, it was shown that infrequent dream recallers had lower activity (measured by brain functional imaging) in the angular gyrus during wakefulness compared with frequent dream recallers (Eichenlaub *et al.*, 2014).

Non-dreamers (or, to be more accurate, non-recallers) represent the extremity in this spectrum of individual differences in dream recall frequency. The incidence of adults who report via a questionnaire that they never dream varies from 2.7 to 6.5% (Pagel, 2003; Pagel and Vann, 1992). However, when questioned by phone, most of the same individuals report 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 (Pagel, 2003). When awakened at the end of REM sleep periods in a sleep laboratory, the same non-recallers did not report any dreams, even when a broad definition of dreaming was used that included thoughts, feelings and emotions (Pagel, 2003). This group of individuals does not differ, based on polysomnographic, clinical or demographic variables, from a comparable group of low dream recallers that occasionally reports dreams when awakened in a sleep laboratory. This finding demonstrates that dreaming may not be a universal experience. Whether these non-recallers have no dream production or recall (despite no obvious memory impairment and a normal ability to maintain an occupation in society) could not be tested because there is no reliable marker of dreaming activity to be contrasted with dream recall.

These fascinating experiments regarding dream recall postulate that dreams are not directly accessible. As a consequence, the study of dreaming has been restricted here to the analysis of recalled sleep mentation after spontaneous or provoked awakening. However, this limitation may be circumvented by the recent discovery of a sleep disorder referred to as REM sleep behaviour disorder (RBD), which is characterised by violent behaviours and enhanced muscle tone during REM sleep (for a review, see Arnulf, 2012). In RBD, middle-aged patients with incomplete muscle atonia during REM exhibit frequent jerks and, more rarely, several complex movements, such as gesturing, reaching, grabbing, arm flailing, slapping, speaking, yelling, swearing profanities, punching, kicking, sitting up and leaping from bed (American Academy of Sleep Medicine, 2005). These often violent behaviours are described by the sleeper as an attempted enactment of distinctly altered, unpleasant, action-filled and violent dreams in which the individual is confronted, attacked or chased by unfamiliar individuals or animals (American Academy of Sleep Medicine, 2005). Non-violent behaviours (e.g. laughing, clapping, singing, giving lectures, eating in the absence of real food, greeting, smoking in the absence of a real cigarette, scoring a goal, and building a staircase) have also been described during RBD, which suggests complex learned behaviours and dreams also exist in this condition, although they are less frequent (Oudiette *et al.*, 2009). Because patients awakened immediately after a behaviour during RBD frequently report a dream content that is congruent with the objective behaviour observed prior to awakening (a condition referred to as isomorphism), these behaviours are believed to represent the acting out of dreams while sound asleep and unaware of one's surrounding (Scaglione *et al.*, 2005). There have been many incidental reports of clear dream–action isomorphism in RBD (De Cock *et al.*, 2007; Oudiette *et al.*, 2009; Schenck, 2005; Schenck *et al.*, 1986; Uguccioni *et al.*, 2013). The adequacy between the actual action performed by patients with RBD during REM sleep and the dream content has been formally assessed in a single study (Valli *et al.*, 2012). Blind judges matched a set of dream contents with the corresponding motor behaviour above the chance level, which was significant in this series of rare scenic behaviours (Valli *et al.*, 2012). In another study, the gaze of patients with RBD (although the eyes are closed, REMs accompany more than half of the behaviour) was in the same direction and plane as the direction of the enacted behaviours (when they were directed towards a goal), which suggests a coordinate behaviour as if it were performed while awake (Leclair-Visonneau *et al.*, 2010). An RBD model has been developed in cats as early as in the 1960s by the Jouvet group (Sastre and Jouvet, 1979). Because these animals displayed apparent dreamlike behaviours (leaping, chasing and fighting) during REM sleep, the RBD was named 'oneiric behaviour'.

In the current study, several patients with RBD with complex behaviours during REM sleep were observed that appeared scenic for the observers, while they did not recall an associated dream; thus, it was aimed to investigate their memory, sleep and dreaming characteristics, and contrast them with patients with RBD and a typical recollection of associated dreams. Because an exact terminology is important on this topic, the term 'dreaming' is used when referring to the presence of subjective experiences during sleep, and the term 'dream recall' when referring to the presence or absence of retrospective recall of previously had subjective experiences during sleep. Additionally, the terms 'non-recallers' and 'recallers' are used instead of 'non-dreamers' and 'dreamers'.

MATERIALS AND METHODS

Patients

Between 2004 and 2014, consecutive patients referred to the sleep disorders unit of Pitié-Salpêtrière university hospital for

suspected RBD underwent a video-polysomnography (v-PSG). Patients were required to meet the International Classification of Sleep Disorders 2005-R for RBD: (i) a history of dream enactment with injurious or potentially injurious movements, in addition to the presence of REM sleep without atonia; or (ii) the presence of abnormal complex behaviour during REM sleep on v-PSG (American Academy of Sleep Medicine, 2005). Muscle tone enhancement was measured on the chin muscle as an amplitude of the electromyogram (EMG) signal at least 30% above the lowest muscle tone measured during the night, with tonic muscle enhancement that lasted more than 50% of each REM sleep epoch (Iber *et al.*, 2007). REM sleep without atonia was specifically defined in this study as enhanced chin tonic muscle tone during more than 18% of the REM sleep time. Idiopathic RBD was defined after a complete interview, as well as a neurological and cognitive examination by a neurologist by the absence of definite criteria for Parkinson's disease (PD; Hughes *et al.*, 1992), dementia [Mini-Mental Status Examination (MMSE) score greater than 24] and other neurodegenerative disorders. Conversely, the diagnosis of PD was performed following international criteria (Hughes *et al.*, 1992).

The same consecutive patients with RBD were systematically interviewed regarding the presence or absence of dreaming. The patients who reported a complete absence of any dreaming and dream recall in the previous 6 months were identified as non-recallers. They were matched with twice the number of recallers with RBD (control group), who were randomly selected among the patients with RBD referred between September 2012 and 2014 who had reported they had a dreaming experience, and were matched two by one for age, sex and disease with the non-recallers. The patients provided their oral consent to allow their clinical and polygraphic measures to be reported in a study. The local Ethics Committee waived written consent, in accordance with French law regarding clinical research, for this report of routine measures.

Cognitive and dream recall evaluations

The patients were interviewed and examined by neurologists at the time of the v-PSG diagnosis to assess the clinical history of the disease. The cognitive status was measured using the MMSE (Folstein *et al.*, 1975). Specific attention was paid to the recall memory item (three words retrieved after 2–3 min of a verbal task, with a score of 0–3). In addition, the patients selected here (non-recallers and their controls) completed a phone interview. They were asked about the presence of dreams during childhood, adulthood and the previous 10 years, as well as their age at the time of the previous dream recall and the actual frequency of dream recalls (per year, month and week). Dreaming was defined as the waking report of any awareness of feelings, thoughts or emotions that had occurred during sleep. This definition was explained to the patient and included 'white dreams', i.e. the feeling of having dreamt without any recall of the content.

Video and sleep monitoring

The patients underwent an attended v-PSG in the Sleep Disorder Unit, which included electroencephalogram (EEG), electrooculogram, chin and leg EMG, nasal pressure, oropharyngeal sounds via a tracheal microphone, chest and abdominal efforts via belts, pulse oximetry, electrocardiogram, and synchronised video and audio monitoring performed under infrared lights. The sleep stages, arousals, periodic leg movements, respiratory events and chin tonic activities (after exclusion of snoring artefacts) were scored according to international criteria. The video recordings were carefully examined to identify any movements, behaviours and vocalisations during REM sleep, and were reported on the scoring of the v-PSG. Any behaviour, vocalisation or movement that occurred during an arousal or at the end of a respiratory event was excluded from the analysis. As violent behaviour may obscure the concomitant EEG, in these instances, the RBD motor signature criteria previously defined by the current group were used to score the sleep stage. Because the v-PSGs were performed for medical purposes, the nurses were instructed not to interfere with the sleep dynamics, to avoid interrupting sleep or prolonging wake after sleep onset. However, they entered the room and woke the patients when they felt the patients were in danger of hurting themselves or when the electrodes were disconnected (due to the violence of movements). In these instances, they asked the patients about their dream recall.

Statistical analysis

Because the sample size was small, the statistics included the median and upper and lower quartiles for quantitative variables, and the numbers and percentages for qualitative variables. The relationships between the qualitative variables were tested using Fisher Exact tests (with correction for the small sample when required), whereas the quantitative variables were compared using unpaired Wilcoxon tests. All tests were two-tailed, and a *P*-value less than 0.05 was considered statistically significant.

RESULTS

Frequency of non-recallers among patients with RBD

Between 2004 and 2014, 79 patients with idiopathic RBD and approximately 210 patients associated with PD were diagnosed with RBD in the sleep disorder unit. Of these 289 patients, eight (2.7%, six men and two women) patients denied having recalled any dream (even white dreams) in the previous 10 years. Furthermore, four (1.4%, three men and one woman) patients reported never having recalled a dream (even white) during their entire life.

Clinical and dreaming histories in non-recallers

The group of eight non-recallers with RBD included six men and two women, and six patients with idiopathic RBD and two patients with PD and RBD (Table 1). Their medical histories are shown via four examples. Patient 1 was a 73-year-old man with no medical history or treatment. He used to recall dream as a child, but stopped recalling dreams from the age of 20 years. At the age of 53 years, he started talking, yelling, and moving his legs and arms while asleep. The episodes became increasingly frequent and occurred every night from the age of 65 years. He woke up several times with bruising on the legs, and no dream recall. During one episode, at the age of 60 years, the patient fell from his bed and went to an emergency department because of a head trauma. His v-PSG indicated sudden movements of his arms and legs during REM sleep, as well as REM sleep without atonia. Sequences of the patient arguing, swearing profanities, kicking, boxing and throwing items towards an invisible individual during REM sleep, as well as fighting again in another REM sleep episode 1 year after, with no subsequent dream recall despite the nurse immediate inquiry, are shown in Videos S1 and S2. The patient had no evidence of any other neurological disease and normal cognition (MMSE 29/30); thus, he was diagnosed with idiopathic RBD. Patient 2 was a 71-year-old man treated for hypertension, with idiopathic RBD for 2 years at the time of his first v-PSG, who developed PD 4 years after. He used to recall dream as a child, but stopped recalling any dreaming experience from the age of 15 years. At the age of 69 years, he started moving during his sleep, kicking and swearing profanities. He had arm and leg movements and spoke during REM sleep on v-PSG. During a violent movement in REM sleep, he hurt his head when he hit it against the bedside table. He woke up, had no immediate dream recall and required stitches. Patient 3 was a 71-year-old woman with idiopathic RBD for 3 years. She never ever recalled any dream. Her v-PSG indicated complex movements and talking during REM sleep (Video S3). Patient 4 was an 80-year-old man treated for hypertension, with idiopathic RBD for 10 years, who developed PD 2 years after the RBD diagnosis. He used to recall dream as a child, had a few dream recalls as an adult, and stopped recalling dreams at the age of 54 years. He started moving during his sleep at the age of 70 years, speaking in French and Spanish, kicking and punching. During v-PSG, which was performed at age 80 years, he had complex arm and hand movement (including pointing) and talked (Video S4). He once fell from bed because of the behaviours, immediately woke up with an injury (and no dream recall) and required stitches.

Table 1 Demographic and clinical characteristics, as well as cognitive evaluation and dreaming frequency in non-recallers versus recallers with RBD

	Non-dreamers	*Dreamers*	P
Number of patients	8	17	
Age, mdn (years)	72 (69.8–75.8)	72 (66–75)	0.70
Sex, % men (*n*)	75 (6)	71 (12)	0.80
Epworth sleepiness score, mdn 0–24	8 (3.8–11.3)	5 (3.5–10)	0.88
RBD			
Idiopathic RBD, % (*n*)	75 (6)	76.5 (13)	0.91
RBD duration, mdn (years)	3 (2–8)	5 (4–8)	0.88
Frequency of RBD per week, mdn	5.3 (3.1–7)	2.8 (1.9–3.8)	0.19
Psychotropic treatment, % patients (*n*)			
No medication	75 (6)	52.9 (9)	0.73
Antidepressant	25 (2)	18 (3)	0.91
Benzodiazepines	25 (2)	18 (3)	0.91
Dopaminergic agents	25 (2)	23.5 (4)	0.67
Others*	12.5 (1)	23.5 (4)	0.91
Cognition based on the MMSE			
MMSE score, mdn 0–30	28 (27.3–28.5)	26 (25–27.8)	0.17
MMSE lower than 27 (%)	12.5 (1)	41.2 (7)	0.33
Recall memory item in MMSE, mdn 0–3	2.5 (2–3)	2.5 (1.75–3)	0.89
Dream recall prevalence and frequency			
Presence of dream recall in childhood (%)	50 (4)	100 (17)	0.009
At time of study, presence of a dream recall in the previous 10 years (%)	12.5 (1)	100 (17)	0.0005
Presence of dream recall in the previous year (%)	0 (0)	100 (17)	<0.0001
Latency to previous dream recall, mdn (years)	59 (51.3–67.3)	0 (0–0)	0.0005
Dream recall frequency, mdn *n* per week	0 (0)	1 (0.75–2)	0.004

MMSE, Mini-Mental State Examination; RBD, rapid eye movement sleep behaviour disorder.
*Other drugs included cetirizin ($n = 1$), melatonin ($n = 2$), levothyroxine ($n = 1$) and clozapine ($n = 1$). Numbers represent the percentages or median (mdn; lower quartile – upper quartile).

Comparison of clinical and cognitive characteristics in recallers versus non-recallers with RBD

At the time of RBD diagnosis in the sleep centre, the eight non-recallers with RBD did not recall any dream for a median of 59 years, whereas the 17 recallers with RBD recalled dreams with a median of 1 dream per week. As expected, because of matching, there were no differences in age, sex or type of neurological disorder (Table 1). The psychotropic treatments and cognitive tests were not different between the recallers and non-recallers with RBD. The dreaming characteristics, including the proportion of patients with dream recalls during childhood, the previous 10 years, and the previous year, as well as the number of dreams recalled per week were lower in the non-recaller group compared with the recaller group. Two of the six patients with idiopathic RBD in the non-recaller group and one of the 13 patients with idiopathic RBD in the recaller group developed PD within 2–4 years after RBD diagnosis.

Sleep characteristics in recallers versus non-recallers with RBD

As indicated in Table 2, there were no differences regarding sleep continuity, latency, stages or fragmentation between the RBD recallers and non-recallers.

Table 2 Sleep measures in non-recallers versus recallers with RBD

	Non-dreamers	*Dreamers*	P
N	8	17	
Sleep continuity			
Total sleep time (mdn, min)	407 (393–459)	378 (307–427)	0.21
Sleep efficiency (% of total sleep period)	72.9 (68.1–82.9)	70.8 (68.8–75.1)	0.63
Wakefulness after sleep onset (mdn, min)	139 (93–169)	135 (95–173)	0.77
Sleep latency (mdn, min)			
Sleep onset	34 (24–46.3)	23 (13–41)	0.49
REM sleep	163 (83.5–200)	97 (87–151)	0.44
Sleep stages (% of total sleep time)			
N1	6 (2.5–9.3)	7 (5.7–11.6)	0.35
N2	56.5 (48.4–62.2)	50.2 (42.6–56.7)	0.49
N3	24.9 (19.7–26.9)	21 (16.7–27.7)	0.67
REM sleep	9.5 (8.2–22.8)	16.2 (13–21.9)	0.42
REM sleep without atonia (%)	44 (30–93.4)	40 (30–71)	0.70
Sleep fragmentation (mdn events per h)			
Arousal index (mdn)	14.4 (8.2–19.3)	10.3 (6.9–19.8)	0.87
Apnea–hypopnoea index (mdn)	6.2 (3.8–11.7)	3.9 (2.8–8.5)	0.76
Periodic leg movement index (mdn)	0.9 (0.5–1.5)	1.5 (0.4–2.1)	0.19

Numbers represent the percentages or median (mdn; lower quartile – upper quartile).
REM, rapid eye movement.

DISCUSSION

Main results

Of the 289 patients with RBD (idiopathic or associated with PD), 2.7% were non-recallers for at least 10 years at the time of RBD diagnosis, and 1.1% were 'true' non-recallers (never-ever any dream recall). Despite the absence of any dream recall, these patients exhibited several complex, purposeful behaviours every night during REM sleep (including gesturing, speaking and swearing profanities), which were suggestive of dream enactment (mostly fighting against other humans). With the exception of a null dream recall frequency, these patients had no other differences regarding their clinical, cognitive and sleep characteristics compared with the other patients with RBD who were matched for age, sex and RBD diagnosis.

Frequency and characteristics of non-recallers in patients with RBD

The low percentage of non-recallers in this large RBD sample is close to the low percentage of non-recallers when they are diagnosed via a face-to-face interview and not by a general questionnaire (Pagel, 2003). Never-ever recallers are even rarer. The 1% frequency identified in the present study is slightly higher than the 0.38% of patients with no dream recall identified in another clinical series (Pagel, 2003). Differences in age (older patients here), sex (mostly male patients in this sample, which is common in idiopathic RBD) and mild cognitive impairment (with decreased short term memory) may decrease the dream recall frequency and increase the proportion of non-recallers in the RBD population compared with previous healthy and clinical series. However, when non-recallers are compared with recallers in the same RBD population, they do not have lower cognition (at least when measured with the MMSE, which may be less subtle than more comprehensive memory tests) and recall the same number of words in the episodic verbal memory test of the MMSE. Non-recallers were not specifically awakened during REM sleep to be interviewed regarding dreaming to ensure the real absence of dream recall, because they were referred to the sleep laboratory for medical diagnosis procedures, hence the sleep process should not be interrupted. However, several non-recallers had sudden awakenings during REM sleep, which were triggered by their violent behaviours in bed (and often required medical attention); despite these opportunities to encode dream recall, they had no dream recall. A low frequency of awakenings during the night is associated with lower dream recall in healthy controls. However, here, the non-recallers had a similar sleep structure (including time awake and arousal index) compared with the regular recallers with RBD. Thus, these findings suggest that

non-recallers with RBD did not lose the ability to recall dreams because of age, sex, cognitive impairment or RBD.

Potential presence of 'dream' enactment during RBD in non-recallers

Even if most behaviours during RBD are followed by isomorphic mental contents following awakening from REM sleep, some rare awakenings are not followed by any dream report. In a questionnaire-based study in 66 patients with PD and RBD, 59.7% of the patients always or often reported a dream content recall following awakening, 33.9% reported it sometimes, and 1.6% never had any dream recall following awakening from RBD (Scaglione *et al*., 2005). Four (15.4%) of 26 patients with PD and clinical RBD never recall a dream following awakening from an RBD behaviour, as reported in a questionnaire (Vibha *et al*., 2011). In a study of six patients with PD who were awakened during RBD and specifically inquired about their dream content, a mean 28.6% of awakenings during the REM-related movements did not coincide with dream recalls (Valli *et al*., 2012), which represents a percentage similar to the 'absent' dream recall identified following 20–30% of awakenings from REM sleep in normal subjects (Nielsen, 2000). However, the patients with PD and RBD in these studies, as well as the non-recallers with RBD reported in the current series have complex movements, behaviours and speeches prior to these sudden awakenings with no dream recall. The video of Patient 1, a never-ever dream recaller, illustrates this finding. This patient has a long, complex and well-organised argument with an invisible individual, to the point that any individual who views this behaviour on a video would know that the dreamer was in fury, insulting and fighting someone. Here is the paradox of RBD: dreams are thought to represent personal experiences; however, in the case of scenic behaviours and complex speeches, an external observer can sometimes know or guess part of the sleep mentation of the dreamers at the place of the dreamers themselves (at least when they have forgotten everything following awakening). Naturally, the observer cannot see the images or hear the sounds heard 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 behaviours may be considered materialised 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. This is a unique condition because there are no other conditions in which one may know at the place of others what they are thinking, with the potential exception of when delusional patients with post-episode amnesia are observed. 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 behaviours without dream recall be classified as dream-enacting behaviour (or apparently dream-enacting behaviour)? At this point, it would be fascinating to compare the functional brain imaging of a patient with RBD during behaviours 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. The question whether the loss of dream recall despite intact REM sleep after some temporo-parieto-occipital lesions may also correspond to absent recall rather than to absent dreaming experience (Bischof and Bassetti, 2004; Murri *et al*., 1985) could be solved if the same patients had in addition some scenic RBD, which suppose a concomitant synucleinopathy.

Limitations

The current study has several limitations, including the limited size of the group of non-recallers with RBD. However, real non-recallers are rare in all series, including individuals with RBD (Scaglione *et al*., 2005). These patients were compared with twice the number of recallers with RBD, and matched for age, sex and disease to reduce the variability not directly linked to the dreaming process. Plus, the observation of complex, scenic behaviours during REM sleep in never-ever recallers is rare and precious information for the conceptualisation of dream memorisation. The evaluation of cognition was limited to a three-word memory test and did not contain a precise investigation of free and cued encoding, as well as short- and long-term retrieval. However, no patient was demented, and most patients had idiopathic RBD, which indicates that their cognition is apparently normal and has no impact on daily life. There were no dream diary and specific awakenings during REM sleep, which are methods that may increase the dream recall frequency. There were, however, several spontaneous (e.g. Video S1) and sudden awakenings during RBD in some patients, which did not evoke any dream recall. In a future, ideal (but extremely difficult) study, one should ask these non-recallers with RBD to come specifically in the sleep laboratory for a dream study, then hope to observe some scenic behaviours and more systematically awake them for trying to obtain a dream recall.

CONCLUSIONS

It was demonstrated that some patients with RBD enacted complex, scenic behaviours suggestive of dream-enacted behaviour, whereas they did not recall any dream for more than 10 years, and some patients had never ever recalled any dream during their entire life. These patients may represent the extremity of the spectrum of dream-enacted behaviour in REM sleep because many patients with RBD do not always remember a dream associated with a violent behaviour. The observation of speeches, facial expressions and behaviours while sleeping, unbeknownst to the dreamers, suggests that dreaming production is universal, while dreaming recall is variable. These findings raise the possibility that non-recallers, even without RBD, also dream

without recollecting this process. It would be fascinating to provide cues (words uttered during RBD, apparent behaviour, apparent emotion) to the never- recallers following awakening from RBD behaviours to determine whether they allow some dreams retrieval. These rare clinical observations and this RBD model should fuel the debate regarding consciousness and dreaming.

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AUTHORS' CONTRIBUTION

The patients were diagnosed, scored and selected by IA and SLS among their patients. BH and CM called and interviewed the patients, collected the information and prepared the first manuscript, which was edited by IA. All authors discussed the results and approved the final version of the manuscript.

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Video S1. Patient 1 has idiopathic RBD and has never recalled any dreams or blank dreams during his entire life. Nevertheless, he presents numerous apparently dream-enacting behaviours during REM sleep. Here, when he is in REM sleep, he starts to kick with both legs, turns his head and yells "*That is something, huh? Come on, speak it! No but*" (French: *ça c'est quelque chose, hein? Vas-y, balance! Non mais*). He then sits, mumbles, says "*You took me something, you will take it in the trap. No slippers, is it so?* (Mumbles) *Ouch! F. shit*!" ("*Tu m'as pris quelque chose, tu*

vas le prendre dans la gueule. Pas de chaussons? Qu'est ce que c'est! marmonne; *Aïe! Putain, merde'*). He stands up, throws the objects from his bedside table and boxes the wall, shouting: "*Tell me what, you will be f.ck off... You will see, you will take that in your trap... You want that in your trap, here? Ouch*" ("*Dis moi ça, Tu vas aller t'foutre, tu vas voir tu vas prendre ça dans ta gueule... Tu veux ça dans ta gueule, là? Aïe!'*). He then sits, calms down and replaces his pillow. The nurse enters the room, and he says to her: "Hello. What?" ("*Bonjour. Comment?*"). The nurse says: "*All is OK*?" ("*Tout va bien*?"), and he says: "*Yes*" ("*Oui*"). He subsequently appears surprised of the mess and helps her clean. His eyes are closed during the first 35 s of the sequence and are then opened. The EEG is scorable (and is in REM sleep) until he stands up, when the recording is disconnected. Although he woke up at the end of this sequence, he had no dream recall. Standing up and opening the eyes are rare but possible during RBD episodes.

Video S2. Patient 1 (never-ever dreamer) during another v-PSG 1 year after the first one, shouts, fights again (kicks and boxes) and swears profanities ["W*hat can I make to eat, I saw,... You listen...* (incomprehensible words, then high-pitched voice) *Stay here before doing such a thing, you b.tch* !"], while in REM sleep, lying on his side.

Video S3. Patient 3 (never-ever dreamer), during REM sleep, eyes closed. She startles, shouts and then says:"*Oh, I apologises*".

Video S4. Patient 4, who does not recall any dream for the last 26 years, has several complex hand movements (suggestive of expelling something, throwing away, catching and pointing) as well as mumbling during REM sleep.