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REM sleep dream mentation in right hemispherectomized patients

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Abstract—Investigations of dream mentation in brain damaged patients have shed some light on the controversial issue of cerebral lateralization of dreaming. To examine further the relationships between brain function and dreaming, we studied REM sleep dream recall and content in four patients having undergone right functional or anatomical hemispherectomy and eight matched control subjects. Patients were found to have the capacity to report dreams to much the same extent as control subjects. Further, the patients' dream content was overall similar to that of the control subjects. The results provide strong evidence that dreaming is not a right-hemisphere function, and that the left hemisphere may be more critical for the generation of dreams. In addition, some characteristics of hemispherectomized patients' dream content (characters, smells) are consistent with the possibility that a history of epilepsy may influence REM sleep imagery over the long term. © 1997 Elsevier Science Ltd.

Key Words: REM sleep; dreaming; hemispherectomy; epilepsy; human.

Introduction

Since the discovery of an association between REM sleep and the recall of vivid dreaming [4, 12], attempts to identify specific neurological generators of dreaming and to determine whether dreaming is a lateralized brain function have been numerous.

Proposals that both dream mentation and, more generally, visual imagery are primarily right hemisphere (RH) processes [5, 8, 24, 44, 57] followed the finding that callosotomized patients have superior spatial information-processing ability in the right hemi-cortex [25, 53]. Studies reporting greater cortical activation in the RH during REM sleep [26, 34, 48] provided further support for the hypothesis that dreaming is a RH function (RH hypothesis).

However, subsequent findings, using EEG-derived indices of brain asymmetry, did not support an exclusive role of the RH in dream formation [2, 3, 14, 22, 50]. Rather, reports of the persistence of dream recall after extensive RH lesions [28] and of total cessation of dreaming after damage to left infero-mesial, occipito-temporal cortex [13, 17] supported the competing hypothesis of a LH role in dreaming [6, 29, 39]. Further, a single case report of dreaming after total right hemispherectomy [36] seemed also to confirm the LH hypothesis.

A general consensus today is that the LH plays a major, perhaps essential, role in the organization of dreaming (perhaps because of its linear, narrative-like structure) and that the RH plays a less important role [1, 7]. No inter-hemispheric transfer of non-verbal information from the RH to the verbalizing processes in the LH seems necessary for either dream activity or recall [29, 42]. Some EEG studies do indicate that relative hemispheric dominance during REM sleep seems to shift between the left and right as a function of both biological and psychological factors [27, 31, 33, 61]. However, results from neuropsychological studies of brain-damaged patients [6, 29, 39] suggest a favored role for the LH in dream mentation.

The study of dream mentation in hemispherectomized patients is of particular interest. Even though studies of dream recall and content in patients with extended cerebral lesions have provided much information about possible neurological generators of dreaming, the study of dream mentation in hemispherectomized patients may provide critical information about relative hemispheric

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contributions to dream mentation. The reporting of dreams by patients having undergone resection of the entire right hemi-cortex would be consistent with studies of acallosal and callosotomized patients that have cast doubt on the RH hypothesis [42]. Moreover, the specific dream contents of patients with such massive hemispheric excisions may provide clues as to the role of the right hemisphere in activating particular types of imagery (e.g. emotion, characters, sensory elements).

Hemispherectomy is a neurosurgical procedure that was first performed at the turn of the century to provide relief to patients suffering from cerebral glioma [10]. It has since been carried out primarily as a last resort for the treatment of infantile hemiplegia, the Stürge–Weber Syndrome, and intractible seizures [60]. Two types of hemispherectomy have been in use since its initial description in the literature [10]. Anatomical hemispherectomy, on the one hand, consists of complete removal of one cerebral hemisphere in which the thalamus, basal ganglia and caudate nucleus are preserved (see cases 1 and 2). This type of surgery is rarely performed today since it often results in superficial cerebral hemosiderosis (SCH), which, in turn, is a basis for obstructive hydrocephaly. Functional hemispherectomy, on the other hand, consists of the partial removal of one hemisphere (temporal lobectomy, resection of central area) and in the disconnection of residual frontal, parietal and occipital lobes (see cases 3 and 4). The risk of SCH is strongly reduced since sub-arachnoid space is preserved on the operated side, enabling the draining of hemosiderine. In addition, functional hemispherectomy is as effective as anatomical hemispherectomy in controling epileptic seizures. It is, thus, considered today to be the surgical procedure of choice [60].

The single case study found in our literature review of hemispherectomy and dreaming reports that dream mentation can occur following right anatomical hemispherectomy, although recall is diminished and content is impoverished [36]. However, in addition to being limited to a single patient, this report involved no sleep laboratory procedures, no qualitative or quantitative measures of either dream recall or content, and no comparisons with control subjects. The goal of the present study was therefore to conduct a controlled experimental investigation of dream recall and content in a larger sample of right hemispherectomized patients, using standardized sleep laboratory and dream mentation sampling procedures. We examined whether right hemispherectomized patients remember dream content when awakened from REM sleep and, if so, whether this content differs systematically from that of subjects with no cerebral insult.

Method

Subjects

One male and three females (mean age: 22.2 years), having undergone right anatomical or functional hemispherectomy to alleviate intractable epilepsy, participated in the study. As a result of surgery, no patient had experienced seizures in the past several years, and only one patient (D.R.) continued to take medication to control epileptic activity.

Case 1. C.F., a 14-year-old female, underwent complete removal of the right cortical hemisphere at age 8 as a last resort for controlling epileptic seizures resulting from birth trauma. A preoperative CT scan and angiogram revealed an infarcted right cerebellar hemisphere in the area of the right middle cerebral artery distribution, an atrophic middle cerebral artery and some mild asymmetry between the right and left sides of the anterior cerebral and posterior cerebral arteries. An anatomical right hemispherectomy was performed, including an anterior to posterior section of the corpus callosum and dissection anteriorly along the caudate nucleus and posteriorly around the basal ganglia. The entire cortex of the frontal, parietal, temporal and occipital lobes was then removed. Since surgery, C.F. has essentially recovered from her epilepsy; she has had no seizures, and her full-scale IQ on the WAIS-R is 68 (verbal IQ = 64; performance IQ = 75).

Case 2. T.H., a 22-year-old female, also underwent anatomical right hemispherectomy. Onset of epileptic seizures occurred at 9 years, following thrombosis of the right middle cerebral artery secondary to a Tetralogy of Fallot. Surgery was performed in the same year as the onset of epilepsy. The entire right cortex and the subcortical ganglion lateral to the ventrical system were removed. The thalamic portion of the caudate nucleus and part of the hippocampus were left intact. T.H. has had no further seizures since surgery. Her WAIS-R full-scale IQ rating is 68 (verbal IQ = 75; performance IQ = 62). She has graduated from high school, is computer literate, and works as an assistant librarian.

Case 3. D.R., a 20-year-old female, underwent right functional hemispherectomy at 5 years to alleviate intractable seizures resulting from chronic encephalitis. Surgery was performed at 17 years and consisted of a fronto-parieto-temporal craniotomy, an anterior temporal lobectomy, removal of the amygdaloid uncal zone and of part of the hippocampus, and subtotal lateral callosotomy. Mild, recurrent, motor seizures are today controlled with anti-epileptic medication. D.R. lives independently from her parents and is finishing a high-school degree (WAIS-R full-scale IQ = 83; verbal IQ = 87; performance IQ = 83).

Case 4. S.E., a 28-year-old male, also underwent right functional hemispherectomy. The onset of seizures occurred at 7 years. A CT scan demonstrated a right proencephalic cyst and cerebral parieto-temporal atrophy with some preservation of the medial occipital lobe and right hippocampus. Surgery was performed at 25 years of age, and consisted of removal of the cyst, a right fronto-parieto-temporal craniotomy, excision of the amygdala, and partial removal of the hippocampus. S.E. is today free of medication, and follow-up neuropsychological assessments confirm an astounding cognitive recovery with a full-scale WAIS-R IQ of 93 (verbal IQ = 90; performance IQ = 99).

Control subjects

Each experimental subject was matched to two control subjects for age, gender, pre-operative hand preference and native language. None reported a history of sleep, neurological or psychiatric problems.

Procedure

Laboratory procedures. Subjects slept for three consecutive nights in the sleep laboratory. All night polysomnograms were recorded with electrodes from the 10–20 EEG montage [38] and the standard EEG, EOG and EMG montage for sleep staging [47]. On nights 1 and 2, dreams were collected from all REM sleep periods, except the first, after a fixed number of minutes from REM sleep onset had elapsed: REM 2, 5 min; REM 3, 10 min; REM 4, 15 min; REM 5, 20 min. Subjects were awakened by a gentle knock on the door. They were then asked whether they thought they had been dreaming and whether they would report verbally whatever they could remember. Free recall of dreams was followed by prompts for the presence of characters (animal, human), a central feature of REM sleep dream narratives [20]. Subjects were also prompted for the presence of contents that have been attributed by some researchers to either right or left hemisphere processes. These consisted of emotions (negative, positive) and sensory elements (smells, sounds, colors). Interviews with all subjects were conducted by the same experimenter. These were tape-recorded and transcribed for later scoring of recall and content.

Recall and content measures. Dream recall from a REM period was defined as the ability to remember and to report verbally any imagery having occurred prior to awakening that was perceived as being real [52]. This variable was assessed for each subject on nights 1 and 2 when a content of five words or more was reported upon awakening. The number of subjects in each group having dream recall once, twice, three times, four times or five times in the course of the same night was then assessed in order to obtain group dream recall distributions.

As these group distributions for REM periods did not differ on either night (N1: $P=0.406$; N2: $P=0.745$), all dreams of at least 50 words were included for dream content analyses. Reports were scored independently by two blind judges, according to standardized criteria [30] for characters, emotions and sensory elements. Scoring for all categories, except emotions, was based on both subjects' free recall of dream mentation and their responses to prompts. The assessement of presence and valence of emotions was based only on responses to prompts in order to rule out the judges' subjective interpretations of emotion in the free recall reports. The interjudge reliability for all categories was at least 98.9%. In order to obtain groups' frequency distributions for each category, we assessed the number of subjects in each group having reported the presence of a specific dream content category in one, two, three, four, five or six dreams in the course of each night.

Statistical analyses

Between-groups differences were assessed for nights 1 and 2 separately, by comparing groups' distributions of frequency levels for dream recall (one dream recalled, two dreams recalled, etc.) and for the presence of each content categories (e.g. presence of animal characters in one dream, in two dreams, etc.), in order to rule out the possibility that dreams from successive REM periods were interdependent. This was achieved by applying Fishers' exact test to the multinomial law. Statistical comparisons for this limited sample size were based upon a liberal two-tailed probability cut-off ($\alpha=0.10$), which was adjusted by a conservative error correction for multiple comparisons. The cut-off alpha value (α_c) was divided by the number of variables examined on each night; thus, $\alpha_c=0.10/8=0.012$.

Results

Dream recall

Right hemispherectomized patients' ability to recall dreams was not found to be impaired. Although patients' mean percentage of dream recall (N1: 84.6%; N2: 76.4%) was slightly lower than that of control subjects (N1: 94.1%; N2: 92.3%), the experimental groups' recall frequency distribution did not differ significantly from that of the control group on either night (N1: $P=0.442$; N2: $P=1.000$) as illustrated in Table 1.

Table 1. Distribution of dream recall on nights 1 and 2 for hemispherectomized patients and control subjects

	Number of dreams recalled				*P* values*
	1	2	3	4	
Night 1					0.442
Number of patients	0	2	1	1	
Number of controls	3	2	3	0	
Night 2					1.000
Number of patients	0	1	1	2	
Number of controls	0	3	2	3	

*Fisher Exact Test; α corrected (α_c) = 0.012.

Dream content

Dreams of patients having undergone complete or partial removal of the right hemi-cortex differed from those of control subjects for the frequency of occurrence of some dream content categories. The results for nights 1 and 2 are summarized in Tables 2 and 3, respectively.

Characters. Patients reported significantly more frequent dreams with animal characters than did control subjects. Although this pattern was only observed on night 2 ($P=0.010$), a trend was also present on night 1 ($P=0.038$). However, patients' frequency distributions of dreams with human characters paralleled those of control subjects on both nights (N1: $P=0.596$; N2: $P=0.798$).

Emotions. On night 1, patients' frequency distributions of dreams with either happiness ($P=0.495$) or sadness ($P=0.236$) did not differ from those of control subjects. Similarly, the frequency distributions of dreams with happy and sad emotions on night 2 are comparable for the two groups (happiness: $P=0.194$; sadness: $P=0.333$).

Sensory vividness. Hemispherectomized patients and control subjects had similar frequency distributions of dreams with sensory components on night 1 (smells: $P=0.661$; sounds: $P=0.818$; colors: $P=0.141$). However, on night 2, patients reported significantly more dreams with olfactory components than did control subjects ($P=0.010$), while the frequency distributions of dreams with sounds and colors were comparable for the two groups (sounds: $P=0.455$; colors: $P=1.000$).

Discussion

Casting doubt on the RH hypothesis

The results of the present study clearly indicate that right-hemispherectomized patients have the capacity to

Table 2. Patients' and control subjects' dream content distributions on night 1

Dream content category			Number of dreams recalled containing the specific content category							P value*
			0	1	2	3	4	5	6	
Characters	Animals	Number of patients	1	0	2	0	1	0	0	0.038
		Number of controls	6	2	0	0	0	0	0	
	Humans	Number of patients	0	2	1	0	0	0	1	0.596
		Number of controls	0	3	3	2	0	0	0	
Emotions	Happiness	Number of patients	1	2	1	0	0	0	0	0.495
		Number of controls	4	4	0	0	0	0	0	
	Sadness	Number of patients	2	2	0	0	0	0	0	0.236
		Number of controls	7	1	0	0	0	0	0	
Sensory vividness	Smells	Number of patients	2	1	1	0	0	0	0	0.661
		Number of controls	6	2	0	0	0	0	0	
	Sounds	Number of patients	1	1	2	0	0	0	0	0.818
		Number of controls	4	2	1	1	0	0	0	
	Colors	Number of patients	0	0	3	0	0	1	0	0.141
		Number of controls	0	5	2	1	0	0	0	

*Fisher Exact Test; α corrected (α_c) = 0.10/8 = 0.012.

Table 3. Patients' and control subjects' dream content distributions on night 2

Dream content category			Number of dreams recalled containing the specific content category							P value*
			0	1	2	3	4	5	6	
Characters	Animals	Number of patients	0	1	3	0	0	0	0	0.010
		Number of controls	5	3	0	0	0	0	0	
	Humans	Number of patients	0	0	1	1	2	0	0	0.798
		Number of controls	0	1	4	0	3	0	0	
Emotions	Happiness	Number of patients	2	0	1	0	1	0	0	0.194
		Number of controls	5	3	0	0	0	0	0	
	Sadness	Number of patients	3	1	0	0	0	0	0	0.333
		Number of controls	8	0	0	0	0	0	0	
Sensory vividness	Smells	Number of patients	0	1	2	1	0	0	0	0.010
		Number of controls	7	1	0	0	0	0	0	
	Sounds	Number of patients	0	1	2	1	0	0	0	0.455
		Number of controls	3	3	1	1	0	0	0	
	Colors	Number of patients	1	0	1	2	0	0	0	1.000
		Number of controls	2	0	1	3	2	0	0	

*Fisher Exact Test; α corrected (α_c) = 0.10/8 = 0.012.

report dreams upon awakening from REM sleep. Patients and control subjects had similar frequency distributions of dream reporting. Moreover, their average percentage of recall (80%) was within the normal range for laboratory studies (81.7% ± 15.0%) [32]. In addition, the content of patients' dreams was, for the most part, very similar to that of control subjects. Thus, neither the ability to recall dreams, nor their global structure was eliminated by major insult to the RH. These findings suggest that the RH is not essential for the elaboration of dreams and is consistent with the hypothesis that the LH plays a critical role in generating dreams [1, 6, 7, 13, 28, 29, 39].

However, an alternative hypothesis also may explain these similarities between patients and control subjects. Neuronal reorganization following early cerebral insult or onset of neurological disease may have enabled the LH to take over possible RH contributions to the generation of dreams. The right hemispherectomized patients' ability to recall dreams may be at least partially due to cerebral plasticity and neuronal sprouting in the intact and/or remaining RH. Some hemispherectomy follow-up assessements have been interpreted to show that the operated brain is functionally plastic: some functions attributed primarily to one hemisphere are relearned or transfered to the other hemisphere following cerebral dysfunction or lesion [51]. Such recovery seems to be partially due to either alternate or newly formed cerebral projections since results from neonatal animal hemispherectomy studies demonstrate novel projections following surgical intervention [59] and an increase in the number of areas that subserve multiple functions [18, 37, 43, 58].

Dream content differences

Despite the overall similarity in dream recall and content of patients and control subjects, some differences in content did stand out. These differences are consistent primarily with the notion that dream mentation may have been altered by a history of intractable seizures having modified brain connections and intellectual functioning.

Characters. The most robust difference in the dream mentation of right hemispherectomized patients is their relative abundance of dreams with animal figures. Some authors who have examined the occurrence of animal figures in children's dreams have suggested that their prevalence may be related to the perceptual and cognitive stimulation that is derived from stuffed animals, children's stories or television programs [19]. In fact, some dreams from our hemispherectomized patients reflected these themes:

> ... A little girl was pushing the wagon. I don't know how old she was. She was wearing a dress of all different kinds of colors. There were stuffed animals in the wagon, a bear, a clown, and smurfs. These animals were smaller than in reality. People were wooden articulated puppets, like Pinocchio.

> ...I had a friend who was in one of the moon's craters. He was with a monkey and a marmot. I went to see him and told him that I was going to fetch someone or that I would stay so that he would have some company. It was in space, we could see all the stars around us. There was a yellow light.

Thus, the patient group's higher frequency of dreams with animal figures may reflect an increased susceptibility to social play influences. However, it has been suggested also that the occurrence of animal characters in dreams reflects one's level of intellectual functioning; the high frequency of animal figures in children's dreams has been found to decrease as age increases [19, 56]. Similarly, intellectually deficient persons consistently report more animal characters on Rorschach Inkblot projective tests than do normal children, college students and depressed or chronic schizophrenic patients [35]. The pattern observed in our patients' dreams thus may be due to the effects of intractable seizures and surgery upon intellectual and social maturity, with animal characters reflecting a developmentally earlier form of this type of character imagery.

On the other hand, that patients report dreams with human figures as frequently as control subjects is consistent with the notion that human character images are a highly stable feature of REM dream narratives. In one study, they appeared in more than 95% of dreams [30]. Major insult to the RH is apparently not sufficient to disrupt portrayal of human characters in all respects and indicates that all person-perception components of dream production may not require the RH.

Sensory elements. Although hemispherectomized patients reported more dreams with olfactory components, this difference occurred only on night 2 and was less robust than the difference observed for animal characters. This tendency is not consistent with the suggestion that the RH contributes to the sensorial vividness of dream experiences [1, 13]. Rather, it seems more compatible with a possible link between post-surgical REM sleep epileptic activity [41] and the olfactory content of dreams.

A relation between epileptic activity and olfactory content was suggested as early as the nineteenth century and prompted the later belief that dreams correspond to an epileptic aura [9]. Several epileptic patients in the Hôpital de la Pitié-Salpétrière in Paris reported terrifying dreams with olfactory components that were similar to those experienced during the hallucinations and auras preceding waking-state seizures [45]. More recently, reports of epileptic patients experiencing olfactory dreams have been published [15, 16]. In contrast to these reports, however, the olfactory components in our hemispherectomized patients dreams were neither terrifying nor exceptionally striking. In fact, the smells were usually positive in nature and only mentioned in response to specific prompts. For example:

> Some people were heating up food, chicken, it smelled good.

> It smelled as in a restaurant.

> There was the smell of fish.

Although dreams with strange olfactory components have more often been reported in patients suffering from partial rather than generalized epilepsy, they may nevertheless exist in a more innocuous form in hemispherectomized patients. Further studies of olfaction in the dreams of epileptic and hemispherectomized patients might reveal whether such content is a function of the intensity of their epileptic activity.

Emotions. Emotional attributes in the dreams of hemispherectomized patients provided few clues as to how the RH and LH contribute to emotional imagery and expression. While several studies of emotional behavior in various populations, including neurologically normal individuals [11, 21], patients undergoing the Wada technique [46, 49, 54], and patients with unilateral cortical damage [23, 55], suggest that the RH is specialized for negative emotions and the LH for positive emotions, others have found this notion too simplistic [40]. The present results indicate that both positive and negative dreamed emotions may be produced by the remaining LH in hemispherectomized subjects. Whether this is also true for waking-state emotional processes was not specifically probed in the present study, but our informal observations of these patients suggested that most maintained an unusually positive mood throughout the sometimes trying experimental procedures.

Conclusions

Results from the present study provide strong evidence against the hypothesis that the RH generates dreams, and in favor of the hypothesis that the LH plays a critical role in dream mentation. In addition, some specific contents observed in right hemispherectomized patients' dreams are consistent with the notion that a history of intractable epilepsy may have exerted a long-term influence on REM sleep imagery.

Because the study sample is small, the differences observed should be regarded with caution. Nevertheless, it is rare to find systematic, controlled comparisons of dream content of brain-lesioned patients and control subjects that have implications for the controversial issue of cerebral lateralization of dream mentation, as well as for understanding the long-term impact of epileptic activity on dreaming.

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