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Déjà-rêvé: Prior dreams induced by direct electrical brain stimulation

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ABSTRACT

Background: Epileptic patients sometimes report experiential phenomena related to a previous dream they had during seizures or electrical brain stimulation (EBS). This has been alluded to in the literature as "déjà-rêvé" ("already dreamed"). However, there is no neuroscientific evidence to support its existence and this concept is commonly mixed up with déjà-vu. We hypothesized that déjà-rêvé would be a specific entity, *i.e.*, different from other experiential phenomena reported in epileptic patients, induced by EBS of specific brain areas.

Methods: We collected all experiential phenomena related to dreams induced by electrical brain stimulations (EBS) in our epileptic patients (2003–2015) and in a review of the literature. The content of these déjà-rêvé and the location of EBS were analyzed.

Results: We collected 7 déjà-rêvé in our database and 35 from the literature, which corresponds to an estimated prevalence of 0.3‰ of all EBS-inducing déjà-rêvé. Déjà-rêvé is a generic term for three distinct entities: it can be the recollection of a specific dream ("episodic-like"), reminiscence of a vague dream ("familiarity-like") or experiences in which the subject feels like they are dreaming (literally "a dreamy state"). EBS-inducing "episodic-like" and "familiarity-like" déjà-rêvé were mostly located in the medial temporal lobes. "Dreamy states" were induced by less specific EBS areas although still related to the temporal lobes.

Conclusions: This study demonstrates that déjà-rêvé is a heterogeneous entity that is different from déjà-vu, the historical "dreamy state" definition and other experiential phenomena. This may be relevant for clinical practice as it points to temporal lobe dysfunction and could be valuable for studying the neural substrates of dreams.

Introduction

Various psychic symptoms, also known as "experiential phenomena" [1], reflect altered contents of consciousness during partial seizures [2]. These include a wide range of déjà-experiences [3], which phenomenology and content-wise vary from déjà-vu (a transitory mental state whereby a novel experience feels as if it is familiar) to reminiscence (the involuntary recall of memories, either semantic or episodic) [4].

Some epileptic patients have reported specific experiential phenomena that appear related to dreams during spontaneous seizures or pre-surgical electrical brain stimulation (EBS). For instance, Van Buren et al. reported that patient MB experienced a prior dream after EBS of a depth electrode in the anteroinferior temporal pole: "I saw something, a dream, a nightmare I had a couple years ago. An object on a table." [5]. Another patient evaluated in our epilepsy center said exactly at the moment of EBS in

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the entorhinal cortex: “I had the reminiscence of a dream I had few a days ago […] Well, I was like in a closed room […] It was very fleeting. I felt the atmosphere of the room […] I saw a color, an orange color.” These examples literally correspond to an “already-dreamed” experience, in other words a “déjà-rêvé” [6]. Dreams correspond to a sensorimotor hallucinatory experience that follows a narrative structure, and these patients seemed to have experienced fragments of it. However, Van Buren and other authors in the following decades were more interested in experiential phenomena in general [1,5,7–11] and did not have many examples of déjà-rêvé. Consequently, no scientific study has ever focused on déjà-rêvé to the best of our knowledge.

An additional reason that probably prevented adequate study of déjà-rêvé is that it has often been confused with déjà-vu. Déjà-vu is common in both healthy subjects and epileptic patients suffering from temporal lobe epilepsy [12–14]. Déjà-vu can also be induced by EBS [15]. Déjà-vu should not be reduced to its literal translation—already seen. According to current and consensual definitions, it corresponds more precisely to a subjective sense of familiarity for an objectively new situation [3,16]. Contrary to other types of experiential phenomena, déjà-vu is devoid of any sense of recollection, as in déja-vécu, and of mental imagery, as in reminiscence [3]. This confusion between déjà-vu and déjà-rêvé dates back to the end of the XIXth century when scientific—and non-scientific [17,18]—authors became interested in psychic phenomena for which no clear definition existed at the time. For example, in psychoanalysis, the feeling of déjà-vu corresponds to the memory of an unconscious phantasy or daydream [19]. Philosophers have also sometimes hypothesized that dreams provide the fragmentary memories later duplicated in the déjà-vu [12,20]. Various interpretations also relate déjà-rêvé to a premonitory dream in mysticism or the reminiscence of an ancestral experience in metempsychosis [21]. Interestingly, experiential phenomena in temporal lobe epilepsy are also grouped under the term “dreamy state” since their description by Hughlings Jackson in 1898 [22]. However, Hughlings Jackson never actually referred to the specific reminiscence of dreams. Instead, he emphasized the fact that experiential phenomena following temporal lobe epilepsy felt like dreaming. Unfortunately, this term is still used in neurology, further adding to the confusion [13].

In the present study, we specifically studied déjà-rêvé induced by EBS in epileptic patients undergoing pre-neurosurgical assessment. We reviewed all the literature reporting déjà-rêvé induced by EBS and added data from our own intracerebral recording database. We aimed to clarify its definition, its phenomenology and its content. As other subtypes of déjà-experiences relate to specific anatomical substrates [4,15,23,24], we hypothesized that déjà-rêvé could be induced by specific EBS locations. Finding clues about the neural correlates of déjà-rêvé could help clinicians focus on specific brain areas in epileptic patients and could increase our knowledge about the neural correlate of dreams.

Methods

Data collection

We first identified EBS-induced phenomena related to dreams in the entire stereoelectroencephalography (SEEG) databases of three French epilepsy surgery centers (Marseille, Toulouse, Nancy) between 2003 and 2015. We then reviewed all publications in the literature that reported experiential phenomena induced by EBS using PubMed and Google Scholar databases from 1958 [7] to 2015. The following keywords were used in our search: “Epilepsy”, “memories” or “memory”, “dreamy state”, “souvenir”, “reminiscence”, “déjà-vu”, “experiential phenomena”, “mental imagery”, “déjà-rêvé”, “dream”. These were combined with the keywords “electrical brain stimulation”, “human brain stimulation”, “brain stimulation”, “electrocorticography”, “deep brain stimulation”, “depth electrodes”, “stereoelectroencephalography”. Animal studies, explicit absence of reference to electrical stimulation in the title, explicit absence of experiential phenomenon in the title, and explicit non-electrical stimulation (such as TMS) in the title lead to rejection of the article. We scanned the abstracts of all the other reports. Out of the 188 publications considered worth reading, and we ultimately selected 29 publications in English or in French dealing with EBS in human subjects. Spontaneous experiential phenomena occurring during seizures were excluded in order to focus on those induced by EBS. Details of this review are available in an open-access database http://gpe.ups-tlse.fr/memstim.php and via a permalink in Figshare: https://figshare.com/s/923f93555a0ce51426e4. DOI: 10.6084/m9.figshare.4733026.

Only experiential phenomena meeting the following criteria were selected:

- Presence of content (visual or auditory) to avoid confusion with déjà-vu and déjà-vécu [3]. Dreams usually correspond to a sensorimotor hallucinatory experience that follows a narrative structure.
- Link to dreams in general: the patient's report had to include the word “dream (y/ed/ing)” or “nightmare”. Elementary visual or auditory hallucinations and other kinds of reminiscence (*e.g.,* semantic or episodic memories) induced by EBS were thus excluded.

Although déjà-rêvé falls into the broad category of the reminiscence of memories induced by EBS ([4] for details), we isolated with these criteria déjà-rêvé from other reminiscences for the purpose of this study. Where available, we collected patients' clinical characteristics, interview following the experiential phenomenon, EBS brain target and EBS electrical parameters (Tables 1 and 2).

Patients in our SEEG database

In our database, every patient suffered from partial epilepsy and anticonvulsant drugs failed to control their seizures. The exact location of the epileptogenic zone could not be specified by non-invasive assessments including MRI, video-EEG and functional imagery such as 18-FDG positron emission tomography in all patients and ictal single positron emission cerebral tomography in some patients. SEEG recording was performed to precisely define the epileptogenic zone. All patients had a comprehensive evaluation including detailed history and neurological examination, neuropsychological testing, routine MRI, surface EEG and SEEG. SEEG was carried out as part of the patients' clinical care. SEEG recordings were performed using intracerebral multiple contact depth electrodes implanted intracranially according to Talairach's stereotactic method (Fig. 1) [25]. Each patient received detailed information about the objectives of the SEEG technique before intracerebral electrode implantation. They also received information about the objective of the EBS, which is a standard clinical procedure and consists in stimulating the brain areas sampled with the intracerebral electrodes in order to assess the local propensity of these brain areas to induce seizures. They signed an informed consent form agreeing to the implantation. High frequency EBS at 50 Hz or low frequency EBS at 1 Hz (pulse duration 1 msec) were applied in a bipolar fashion to each contact in the gray matter (Fig. 1), generally during a 5-s period. The current was gradually increased from 0.5 to 2.5 mA. These are the standard electrical parameters used in clinical practice in French epilepsy centers

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Table 1
Déjà-rêvé induced by EBS in our database.
P. Patient, F: Female, L: Left, M: Male, Hand. Handedness, Ep. Experiential phenomenon, EZ: Epileptogenic zone, R: Right, STG: Superior temporal gyrus, AD: Afterdischarge (transient EEG change after electrical brain stimulation, easily observed in intracranial recording and corresponding to a burst of epileptiform activity induced by the electrical stimulation), Rem. Reminiscence."?": Data missing. * Exact intensity unknown. Electrode contact name: e.g. TB5-6, TB is the name of the electrode, 5-6 means that a bipolar stimulation has been delivered between contacts 5 and 6 of the electrode. Electrode contacts where EBS induced different experiential phenomena are underscored.

P. (Ep)	Content of déjà-rêvé	Type	Age/ Sex/ Hand.	Dreamy state during seizures	Brain lesion	EZ	EBS localization inducing déjà-rêvé (hemisphere/ electrode contact name)	Total EBS on the same site whether inducing an Ep or not	Other EBS with experiential phenomenon (hemisphere/contact/ location)	EBS type (frequency/ pulse duration)	AD spread	EBS intensity (mA)
1(a)	The reminiscence of a **dream** he had had the previous night, involving a scene from everyday life (a discussion with a colleague in their workplace).	**Episodic-like**	35/M/?	No	None	Frontal (L)	Perirhinal cortex (L/TB5-6)	?	Lacking data	Depth elec. (50 Hz/ 1 ms)	None	1.5
2(a)	Doctor: 'What did you feel?' Patient: 'Something that was in my **dreams**. […] Well, actually it was with a friend. We read a comic. […] And in fact, it was a **nightmare**. And then after there is a big beetle coming.' Doctor: 'Was it a nightmare you had long ago?' Patient: 'Yes. […] I was 3–4 years old.'	**Episodic-like**	8/F/R	No	Temporo-insular gyration abnormality	Temporal (R)	Perirhinal cortex (R/TB3-4)	4	**4 EBS = Semantic memories** (R/T1-2,T2-3,T3-4/STG) **3 EBS = Semantic memories** (R/TB1-2, TB3-4, TB4-5/ entorhinal & rhinal cortex) **2 EBS = Episodic memories** (R/T3-4/STG) **1 EBS = Personal semantics** (R/TB3-4/rhinal cortex)	Depth elec. (50 Hz/ 1 ms)	Temporal Cingulate Occipital	1
3(a)	Patient: 'Yes I have seen something I have already seen. […] Something I have seen in a **dream**. […] It was shapes.' Doctor: 'Is it an object of a scene with people?' Patient: 'A scene.' Doctor: 'Can you draw it?' Patient. 'No. […] There was a person. […] In the back of the room. […] The back of the room was yellow.' Doctor: 'Was it moving or was the person static?' Patient: 'The person was moving. […] It was like a short movie.' Doctor: 'Did you know that person?' Patient: 'No but I had the feeling I have already seen her. […]' Doctor: 'Did you see her face?' Patient: 'Yes.'	**Familiarity-like**	12/F/R	No	Right temporal dysplasia	Fronto-temporo-insular (R)	Antero-medial part of temporal pole (R/TP5-6)	1	**3 EBS = Déjà-vu** (I3-4/posterior hippocampus/R)	Depth elec. (50 Hz/ 1 ms)	None	(1-2)*
4(a)	Patient (reading): 'Now, I had a reminiscence of a **dream** I had few days ago.' Doctor: 'What was this dream?' Patient: 'Well I was like in a closed room and everything … A kind of … In a room, I felt … It was very fleeting, I felt the atmosphere of the room in which I was in that **dream** … ' Doctor: 'You felt the atmosphere, but did you see the room?' Patient: 'Yes. I saw the color. An orange color. […] It should be a **dream** I had yesterday or 2 days ago.'	**Episodic-like**	30/F/R	Déjà-vu/ Déjà-vécu	Posterior peri-ventricular heterotopia	Temporal plus (bilateral)	Entorhinal cortex (R/TB1-2)	4	**1 EBS = feeling of losing consciousness** (R/TB1-2/entorhinal cortex)	Depth elec. (50 Hz/ 1 ms)	Medial temporal	(1-2)*

(*continued on next page*)

Table 1 (*continued*)

P. (Ep)	Content of déjà-rêvé	Type	Age/ Sex/ Hand.	Dreamy state during seizures	Brain lesion	EZ	EBS localization inducing déjà-rêvé (hemisphere/ electrode contact name)	Total EBS on the same site whether inducing an Ep or not	Other EBS with experiential phenomenon (hemisphere/contact/ location)	EBS type (frequency/ pulse duration)	AD spread	EBS intensity (mA)
5(a)	Doctor: 'What do you feel? Patient: An abnormal feeling.' Doctor: 'What was it? Patient shows his stomach. […]' Doctor: 'Was there something else? […]' Patient: 'It was strange. It made me immediately think about things I have already seen. Like **nightmares**.' Doctor: 'Were they new images? Was it the room where we are? […]' Patient: 'No, images like in **dreams**.' Doctor: 'What kind of dreams?' Patient: I was in a hospital. I did not know what I was doing.' Doctor: 'And did you feel that it was something recent or old?' Patient: 'Recent.' Doctor: 'Was it in that room or in another room?' Patient: 'I think it was not in that room. This feeling came to me as an image. It is difficult to explain.'	**Dreamy state**	28/M/R	Déjà-vu/ Déjà-vécu/ Rem.	Hippocampal sclerosis	Temporal plus (bilateral?)	Hippocampus (R/B1-2)	2	None	Depth elec. (50 Hz/ 1 ms)	Medial temporal	1
5(b)	Doctor: 'Do you feel something?' Patient: 'Yes (showing the epigastric region). […]' Doctor: 'Is there something else with that feeling?' Patient: 'An image. […] A vision of images that I had in a **dream** that night, which appeared to me now.' Doctor: 'Was it a vision? A scene?' Patient: 'Yes a scene.' Doctor: 'With characters?' Patient: 'Yes, with characters. […] It was indoor. […] I don't remember who it was. […] It was recent.'	**Familiarity-like**					Hippocampus (R/B2-3)	1		Depth elec. (50 Hz/ 1 ms)	Medial temporal	1
6 (a)	Patient (reading): 'Now, I don't know, I don't know … […] Well, when I started to read, I had a feeling of **déjà-rêvé**. I don't know if I had **dreamed** about it that night. I thought of something I **dreamed**. And I had the feeling of fear. […] Well, I saw a character and I thought I saw him in a **dream**. […]' Doctor: 'And did you feel that this feeling of "already dreamed" was a dream you had last night?' Patient: 'That's what I told myself.'	**Familiarity-like**	27/M/R	Rem.	None	Temporal plus (bilateral)	Hippocampus (R/B1-2)	1	**1 EBS = Familiar element** (L/B′1-2/hippocampus) **1 EBS = Familiar elements** (L/TB′4-5/perirhinal cortex) **1 EBS = Personal semantics** (L/B′1-2/hippocampus) **1 EBS = Déjà-vu** (R/TB2-3/entorhinal cortex) **1 EBS = Déjà-vu** (L/TB′2-3/entorhinal cortex) **3 EBS = Déjà-vu** (R/B2-3, B3-4, TB2-3/ hippocampus)	Depth elec. (50 Hz/ 1 ms)	Medial temporal	1

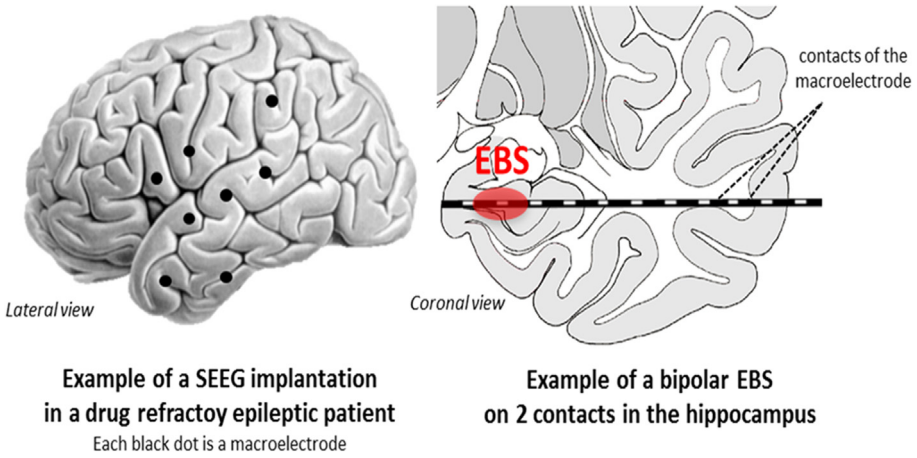

Fig. 1. Methods for collecting déjà-rêvé induced by electrical brain stimulation in our stereo-EEG (SEEG) database.

[4,13,23,24]. Patients were not aware of when EBS was applied and the standard protocol included mock trials in which the patients were asked if they had felt anything when no EBS was applied. Each site was stimulated a variable number of times depending on clinical constraints and the initial clinical EBS results. The déjà-rêvé reported in this study are those collected during this standard clinical procedure. Patients were retrospectively selected if they reported experiential phenomena corresponding to the inclusion criteria defined above during the stimulations. The use of the data included in our study was approved by the ethics committee CPP Est III (Clinical trial NCT 01090934) and by the institutional Review Board of the French Institute of Health (IRB00003888, FWA00005831).

Analyses

We analyzed the data from the literature and the data from our own SEEG database separately, as we have the full verbatim report and interview, the technique used, the different EBS parameters and the electrode location in our patients. Note that in many instances, only partial information could be retrieved from the published articles, in particular in articles from the 1960s to the 1980s.

Two evaluators (JC, EB) working in the fields of neurology and cognitive neuroscience first analyzed the content of each experiential phenomenon meeting the previous criteria independently. Second, they defined different simple categories to classify them on a scale that ranged from: 1) not classifiable, 2) feeling like in a dream, 3) recall of elements of a dream. After reading the reports, it became apparent that category three could be subdivided in two, one for which reports lacked detail and another for which reports were detailed and referred to a specific dream. Specific definitions and terminology was then devised (reported in the Results section). Experiential phenomena were then independently classified by each of the two evaluators, with the final category corresponding to a consensus among the evaluators. If the two evaluators independently agreed on the same category, this category was automatically chosen. If the two evaluators disagreed, the content of the reminiscence was re-analyzed jointly. If the discussion led to a consensus category, this category was chosen. If no consensus could be reached, the report was placed in the "unclassifiable" category.

For our database data, the EBS locations were represented on a schematic brain map. The post-implantation CT-scan was fused with the pre-implantation 3D T1-weigthed MRI. Approximate MNI coordinates of each bipolar contact leading to a déjà-rêvé were then computed and a schematic overview of the contacts of interest was then generated using BrainNet Viewer [26].

Statistical analyzes were performed with Statistica (data analysis software system) using χ^2 tests. Statistical analyzes were carried out for all data in the two groups (literature and our database) comparing the effects of EBS location (lateral *vs* medial, right *vs* left hemisphere) and types of déjà-rêvé. A p value < 0.05 was considered significant.

Results

We collected 7 experiential phenomena related to dreams out of 45 different types of reminiscences (for details about these other types see [4]) in 6 patients (Table 1) from our database. From the literature, we identified 35 experiential phenomena matching our inclusion criteria in 23 patients from 8 publications (Table 2).

In the literature, the publications do not always specify the total number of patients in the source database or the total number of EBS (producing experiential phenomena or not). Thus, the prevalence of déjà-rêvé could not be estimated. With our database, we estimated the prevalence of déjà-rêvé to be about 0.3‰ of all EBS. This can be compared to the overall prevalence of reminiscence induced by EBS—déjà-rêvé included—which was estimated to be around 1.9‰ (detailed in [4]).

Phenomenology of déjà-rêvé

The reports of the 42 déjà-rêvé were analyzed to determine why and how patients referred to dreams. Three different types of reports were identified (Figs. 2 and 3), which were used to classify most of the phenomena (all 7 in our database, 19 from the literature):

- Recollection of a specific dream – "Episodic-like" (3 in our database, 3 from the literature). This is the reminiscence of a specific dream induced by EBS, contextualized in time (e.g. EBS 1a, 2a and 4a; Table 1). The patient is spontaneously able to specify that he/she had this specific dream on a specific date. Note that even in this case, patient reports are not very detailed, like in healthy subjects trying to recall their dreams.
- Reminiscence of a vague dream – "Familiarity-like" (3 in our database, 1 in the literature). This is the reminiscence of elements (character, scene or place) the patient thinks he/she has

Table 2
Déjà-rêvé induced by EBS in the literature.
All but one of the patients suffered from refractory epilepsy involving the temporal lobes. AD: Afterdischarge. A: Ambidextrous. EBS: Electrical brain stimulation. Elec.: Electrodes. EZ: Epileptogenic zone. Rem.: Reminiscence. F: Female. Hand.: Handedness. L: Left. M: Male. R: Right. "?": Data missing.* Exact intensity unknown.

Source	Patient	Experiential phenomena	Age	EBS location	Dreamy state in seizures	EBS Hemisphere	EBS Technique	Type
Baldwin, 1960	E.O.	'I dreamed (one night) my dad was in the shoe business.'	17	Medium temporal gyrus	?	L	Awake surgery	**Unclassifiable**
Van Buren et al., 1961	M.B.	'I saw something, a **dream**, a **nightmare** I had a couple years ago. A **dream** of an object lying on a table.' 'A feeling in the stomach and chest […]. I might have a spell.'	19	Antero-inferior temporal pole	Yes	?	Depth elec. (60 Hz/2.5 ms)	**Episodic-like**
Van Buren et al., 1961	M.B.	Stimulation both of the medial and laterally lying electrodes produced 'a funny feeling like passing out' (she was unable to define it), 'I feel like I dreamed it,' later 'like something I had seen - like I am floating.' With further questioning and restimulation she still was unable to define the sensation saying, 'I can't remember it.'	19	Antero-inferior temporal pole	Yes	?	Depth elec. (60 Hz/2.5 ms)	**Dreamy state**
Van Buren et al., 1961	M.B	Restimulation with the same parameters caused him to make the same remark. Later with stimulation he remarked that he had had a 'different dream but I have forgotten.'	19	Antero-inferior temporal pole	Yes	?	Depth elec. (60 Hz/2.5 ms)	**Unclassifiable**
Van Buren et al., 1961	M.B.	On restimulation he said: 'In a dream I have had before, a monkey doing something impossible.'	19	Antero-inferior temporal pole	Yes	?	Depth elec. (60 Hz/2.5 ms)	**Episodic-like**
Penfield, 1963	R.B.	Stimulation without warning. He said, 'Now I hear them.' Then he added, 'A little like in a dream.'	21	Superior temporal gyrus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	R.B.	'People's voices.' When asked, he said, 'Relatives, my mother.' When asked if it was over, he said, 'I do not know.' When asked if he also realized he was in the operating room, he said 'Yes.' He explained it seemed like a dream.	21	Superior temporal gyrus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	R.W.	He said nothing for a short interval, and then he said, 'Oh, gee, gosh, robbers are coming at me with guns!' He heard nothing, he just saw them coming at him. The robbers seemed to have been coming at an angle from the left. When asked if they came in front of him, he said no they were behind him. This seems to be the reproduction not of a real event, but of a fantasy or a dream drawn from the reading of a comic book, a silent fantasy devoid of auditory components.	12	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Penfield, 1963	M.G.	After stimulation was over she said, 'I had a dream—I wasn't here.' She said it was not like the dreams she had had before.	16	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Penfield, 1963	M.G.	Repeated without warning. Patient said, 'Dream.' After stimulation was over she seemed to find it difficult to explain for a time. Finally, she said it was gone. She said, 'I seemed to be here, but things sounded different.' She also heard a lot of 'funny sounds'.	16	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Penfield, 1963	M.G.	Repeated. 'Another dream. People were coming in and out and I heard boom, boom, boom.' She said, 'I don't remember the rest.'	16	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	M.G.	It's a dream. There are a lot of people—I don't remember the rest. When asked whether she heard or saw people, she said, 'I don't seem to see them—I hear them. I don't hear them talking, I just hear their feet.'	16	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	C.Ft.	Patient said, 'Very faint dream came back.'	27	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Penfield, 1963	G. L.	She reported, 'Something coming to me from somewhere. A dream.' When asked whether it was like an attack, she said, 'Yes.'	29	Parahippocampal gyrus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	G. L.	She said, 'Wait a minute, something flashed over me, something I dreamt.'	29	Superior temporal gyrus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Familiarity-like**
Penfield, 1963	G. L.	She said, 'I keep having dreams.'	29	Hippocampus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	G. L.	Repeated. 'I keep seeing things—I keep dreaming of things.'	29	Hippocampus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	H.P.	She said she felt as though she might have had an attack. When asked what she meant, she said, 'I had that dream, but it passed over.'	16	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**

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Table 2 (*continued*)

Source	Patient	Experiential phenomena	Age	EBS location	Dreamy state in seizures	EBS Hemisphere	EBS Technique	Type
Penfield, 1963	H.P.	Repeated. 'I am seeing somebody.' When asked if it was the same sort of thing she sees in the dream, she said, 'Yes.'	16	Medium temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Penfield, 1963	H.P.	Stimulation was continued for something less than a minute. Patient said she felt dizzy. 'A dream is starting. There are a lot of people.' When asked if they were speaking, she said she did not know. When asked where they were, she said, 'In the living room. I think one of them is my mother.'	16	Medium temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	S.Be	Repeated without warning. After withdrawal of the electrode, he said 'Someone was speaking to another and he mentioned a name but I could not understand it.' When asked whether he saw the person, he replied, 'It was just like a dream.' When asked if the person was there he said, 'Yes, sir, about where the nurse with the eyeglasses is sitting over there.'	25	Superior temporal gyrus	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	N.C.	'I had a dream. I had a book under my arm and I was talking to a man. The man was trying to reassure me not to worry about the book.' When asked, she said she did not know what the book was or who the man was.	23	Medium temporal gyrus	No	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	N.C.	Repeated without warning, 20 min after the previous stimulation at this point. When asked afterward if she had noticed anything, she said, 'I noticed I was having a dream, but I do not know what it was, it was crazy.'	23	Medium temporal gyrus	No	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	N.C.	'Another dream, crazy.'	23	Medium temporal gyrus	No	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Dreamy state**
Penfield, 1963	G.E.	'I see the nurse.' When asked afterward, she said, 'It was a little dream.' She saw the nurse just as she is now.	22	Occipital	Yes	R	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Penfield, 1963	H.N.	The patient said, 'I had a dream.' When he was asked if it was like an attack, he replied, 'Not the way they used to be.'	19	Superior temporal gyrus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Penfield, 1963	H.N.	The patient said suddenly, 'I am starting to get this dream! I can't hear.'	19	Superior temporal gyrus	Yes	L	Awake surgery (40-100 Hz/ 2.5 ms)	**Unclassifiable**
Weingarten et al., 1976	53(a)	The patient felt as though she were having a recurrent dream in which she saw 2 dogs in her old house.	24	Hippocampus	Yes	R	Depth electrodes (10 Hz/ 100 μs)	**Episodic-like**
Weingarten et al., 1976	36	Feels like a dream.	?	Medium temporal gyrus	Yes	L	Depth electrodes (10 Hz/ 100 μs)	**Unclassifiable**
Halgren et al., 1978		Dream-like hallucinations were reported by 3 of the 36 patients (No. 16, 49, and 53). Hallucinations of formed visual images were classified as dream-like if they were described by the patient as being like a dream, day dream, movie, television program, or cartoon.	?	Medial temporal lobe	?	?	Depth electrodes	**Unclassifiable**
Bancaud et al., 1994	19	A second right amygdala stimulation evoked 'a feeling of déjà-vécu, like a dream, a little odor, things seem far away, I have fear—it is my seizure'.	31	Amygdala	?	R	Depth electrodes	**Unclassifiable**
Blanke et al., 2000	A.M.	The patient described that 'I feel that I'm in a castle' and 'it is a little bit incoherent, like in dreams' and that 'it seems to me that it is never the same subject, each time it is a different thing.' On questioning she described her sensations as neutral and said that 'it leaves her totally unaffected, as if I would be outside things' and 'as if the things would be passing me, I'm there, but I do not feel concerned, it is as if I would be watching TV and not paying attention to the film.'	27	Lateral frontal cortex	Yes	L	Subdural grids	**Dreamy state**
Blanke et al., 2000	D.K.	She repeatedly reported the presence of a 'young, tall man with short black hair in a white coat' in the neighboring room to her right, i.e., in the contralateral space with respect to the stimulated hemisphere. The sensation was described as 'an idea or a thought, like dreaming.' The room in which she located the man was the adjacent EEG laboratory, the door of which was closed at the time of stimulation.	18	Lateral frontal cortex	No	L	Subdural grids	**Unclassifiable**
Vignal et al., 2007	16.40	Dream	27	Hippocampus	Yes	L	Depth electrodes	**Unclassifiable**
Vignal et al., 2007	12.28	Familiar dream	18	Amygdala	Yes	L	Depth electrodes	**Unclassifiable**

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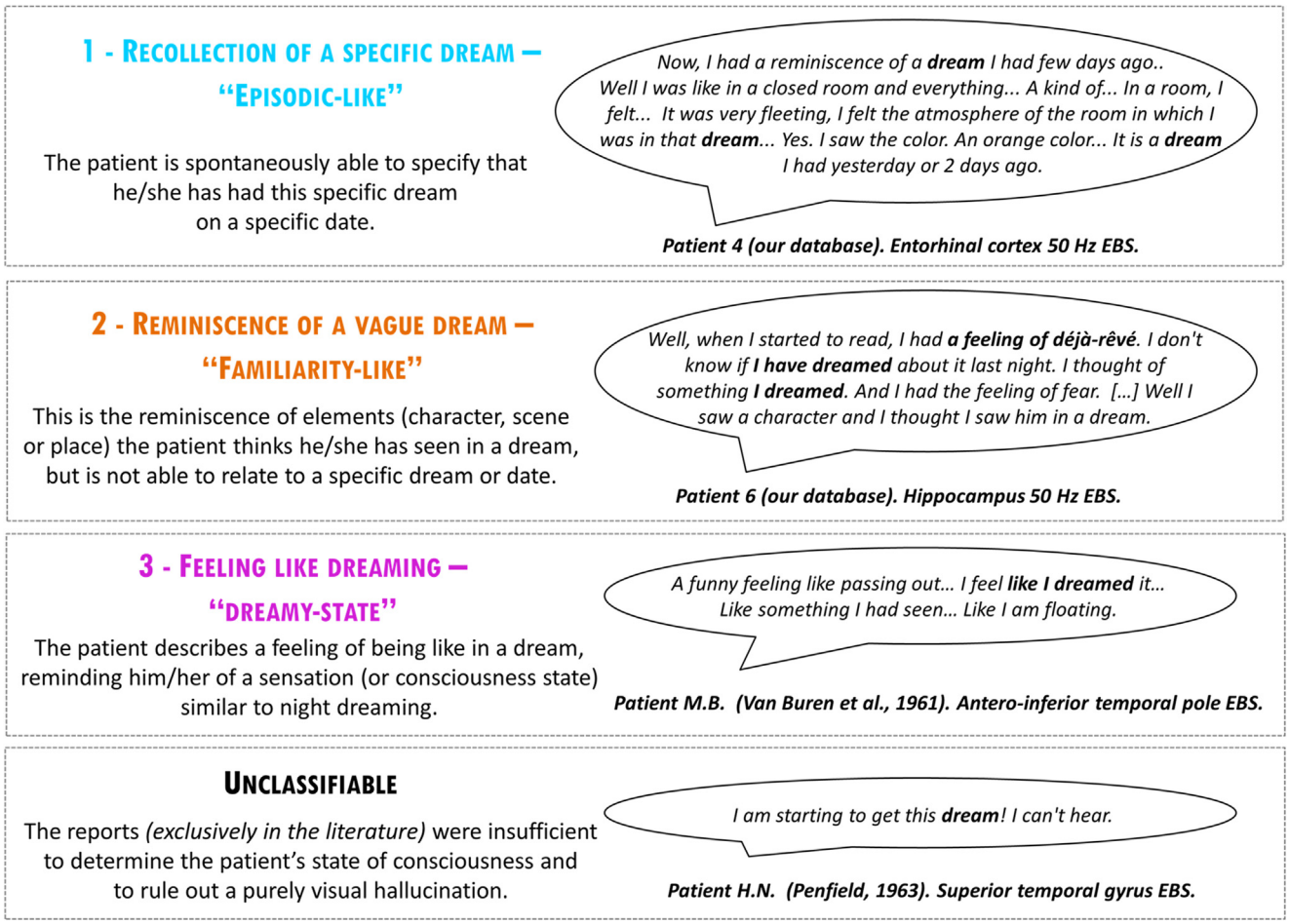

Fig. 2. Déjà-rêvé is a heterogeneous entity with 3 different types. The definition and a specific example are given for each different type, and also for the unclassifiable category.

seen in a dream, but is not able to relate to a specific dream or date (*e.g.,* EBS 3a, 5b, 6a; Table 1).

- Feeling like dreaming – This corresponds literally to a "dreamy state" (1 in our database, 15 from the literature). The patient describes a feeling of being like in a dream, reminding him/her of a sensation (or consciousness state) similar to night dreaming (*e.g.*, EBS 5a; Table 1).

As outlined in the Introduction, "dreamy state" (especially in earlier publications) is not necessarily related to dreams and can be used erroneously to describe a variety of phenomena that alter a subject's perception of reality. For this reason, 16 phenomena from the literature could not be classified in the above categories. The reports in these cases were insufficient to determine the patient's state of consciousness and to rule out a purely visual hallucination. Only the 26 classifiable phenomena were analyzed further.

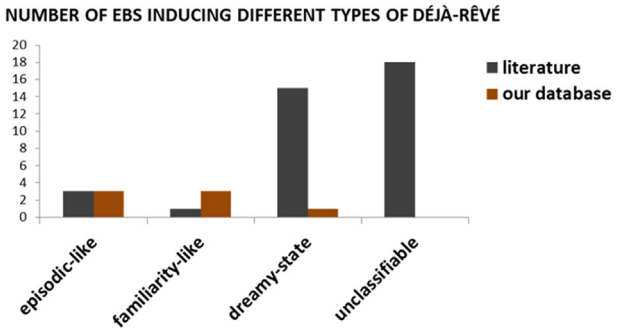

Fig. 3. Number of EBS inducing different types of déjà-rêvé.

EBS locations inducing déjà-rêvé

Although the locations of all EBS during typical presurgical procedures cover various brain areas (Fig. 4-A), all EBS-inducing déjà-rêvé were performed on the temporal lobes—12 on the right hemisphere, 11 on the left (Fig. 4-B). Lateralization was not specified in three cases. All EBS in our database that induces déjà-rêvé were applied on the medial temporal lobes, 85.7% (six EBS) on the right hemisphere. Three were in the hippocampus, two in the perirhinal cortex, one in the entorhinal cortex and one in the medial temporal pole close to rhinal cortices. EBS from the literature were located in the lateral temporal cortex (seven in the superior temporal gyrus, four in the middle temporal gyrus) and in the medial temporal lobe (three in the temporal pole, three in the hippocampus, one in the parahippocampal gyrus). One EBS of the "dreamy state" subtype was located in the inferior frontal gyrus.

Significant differences were found between our database and the literature. All EBS were located on the medial temporal lobes in our database. Considering our database and the literature, déjà-rêvé was most frequently induced by medial temporal EBS compared to lateral temporal lobe EBS (χ^2 (1, N = 25) = 7.63, p = 0.005). A majority was applied on the right hemisphere (χ^2 (1,

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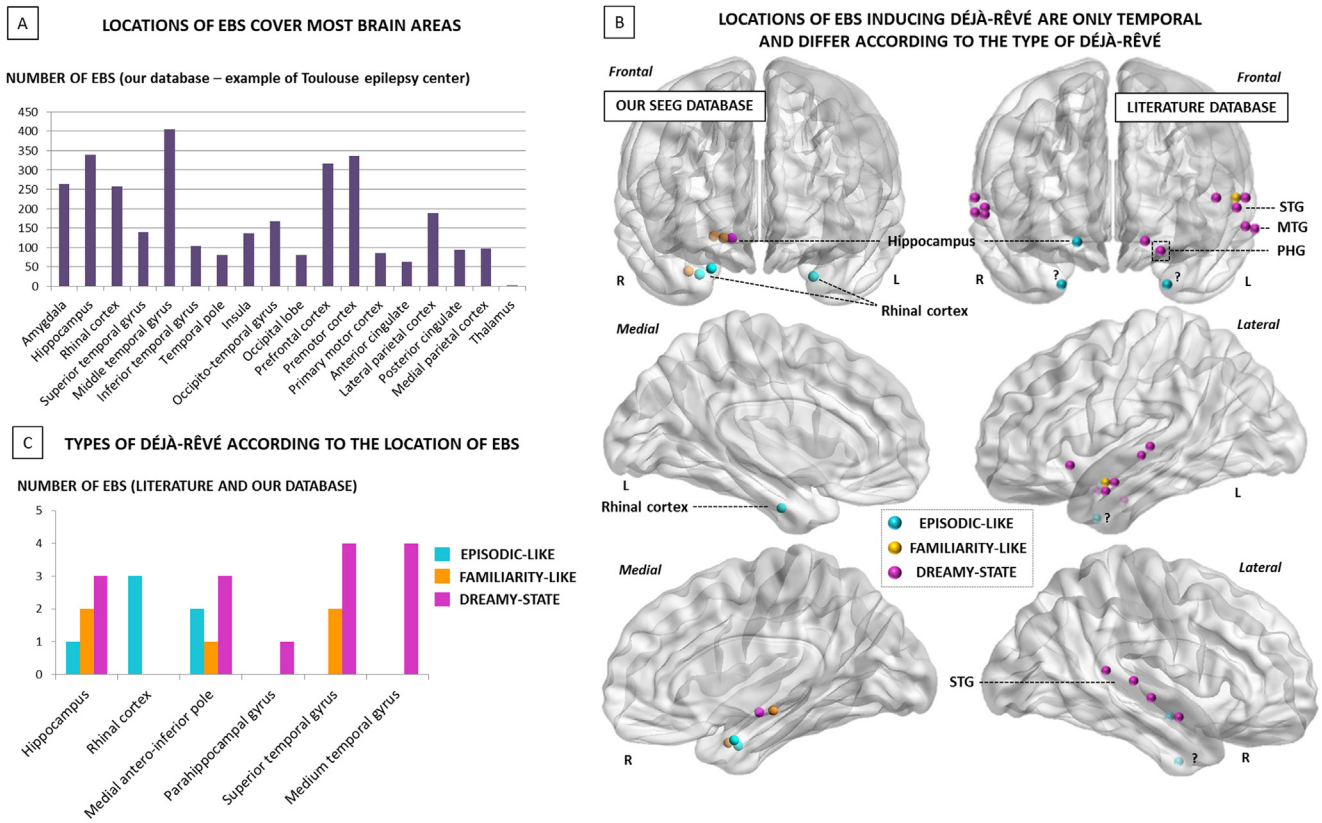

Fig. 4. Locations of EBS influence the type of déjà-rêvé. A – Total number of EBS and their location from the Toulouse epilepsy center database: 3626 EBS were performed between 2003 and 2015 on various brain areas. This figure demonstrates that all brain areas are commonly stimulated. B – Approximate locations of EBS sites inducing déjà-rêvé in our database and in the literature. Two EBS from the literature induced episodic-like déjà-rêvé that were located in the anteroinferior temporal pole but their side (right/left) was not specified by the authors [5]. The figures were produced with Brain Net Viewer [26]. Only the medial views from our database and the lateral views from the literature database are shown to make it easier to view the EBS locations. C – Number of EBS inducing the different types of déjà-rêvé according to the EBS locations. Data from our database and data from the literature were pooled. In our database, EBS was located exclusively in the medial temporal lobes, mostly on the right hemisphere. EBS inducing "episodic-like" déjà-rêvé were all located on the medial temporal lobes. EBS inducing "familiarity-like" déjà-rêvé were also mostly in medial temporal lobe. The distribution of EBS inducing "dreamy state" was more diffuse and mostly on the lateral neocortex. We can conclude that locations of EBS inducing the different types of déjà-rêvé are only temporal and differ according the type of déjà-rêvé. Rhinal cortex: entorhinal and perirhinal cortices. R: Right, L: Left, MTG: Medium temporal gyrus, PHG: Parahippocampal gyrus, STG: Superior temporal gyrus.

N = 26) = 6.03, p = 0.014). Furthermore, a lesser proportion of the "dreamy state" subtype was found in our database (χ^2 (2, N = 26) = 9.79, p = 0.007), when the three types of phenomena were compared in both groups (Table 1 and Fig. 3 for details).

If we consider our database and the literature, and focus on the content and type of the phenomenon, electrode contacts for which "episodic-like" déjà-rêvé was triggered by EBS were all located in the medial temporal lobes: three in the rhinal cortex (two were perirhinal and one was entorhinal), one in the hippocampus and one in the medial temporal pole. "Familiarity-like" déjà-rêvé was also mostly induced by medial temporal lobe EBS. The distribution of the "dreamy state" subtype was more diffuse and mostly on the lateral neocortex (Fig. 4B-C).

In our database, four patients experienced other experiential phenomena after EBS, such as déjà-vu or reminiscence of memories different from déjà-rêvé (Table 1). Importantly, the EBS-inducing déjà-vu and déjà-rêvé was never in the same location, *i.e.*, involved the same contacts, although contacts could be adjacent. For example, patient 6 experienced a déjà-vu three times and a déjà-rêvé one time after right hippocampus EBS. However, these experiences did not involve the same contacts. Results are different for reminiscences since two of our patients (patients 2 and 4) who experienced déjà-rêvé after EBS reported other types of reminiscence, such as personal semantic and semantic memories, after EBS of the same contacts (Table 1).

Electrical parameters of EBS inducing déjà-rêvé

Only high-frequency EBS induced déjà-rêvé (>40 Hz). Because of lack of details and data in the literature, it was difficult to isolate the other electrical parameters leading to déjà-rêvé.

Discussion

Our study is the first to demonstrate the existence—at least in epileptic patients—of déjà-rêvé as a specific experiential phenomenon reported after EBS. This is a neurological phenomenon that can be induced in epileptic patients like déjà-vu and reminiscence [4,7,8,10–13,15,23]. Déjà-rêvé, like EBS-induced reminiscence, is very rare in the literature and in our database [4]. We identified 7 instances of déjà-rêvé among 45 different types of reminiscence associated with content in our database, which is a higher proportion than in the literature. This discrepancy suggests that the prevalence of déjà-rêvé may have been underestimated overall. Further work needs to be carried out to determine if déjà-rêvé can spontaneously happen during seizures or in other medical conditions like déjà-vu happens [3,14].

Déjà-rêvé appears to be different from déjà-vu—the two must not be confused. By construction, all déjà-rêvé episodes we collected had content, which is not the case for déjà-vu. Furthermore, déjà-vu and déjà-rêvé never involved the same bipolar

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contacts in the instances when both could be induced by EBS in the same patient. These results are critical since they support the idea that déjà-rêvé is a true phenomenon, different from déjà-vu.

Moreover, déjà-rêvé is a generic term for distinct entities: recollection of a specific and detailed dream similar to an episodic memory, reminiscence of a vague dream or elements of dream(s) which feels familiar, and finally experiences that resemble or feel like what happens during dreams. Explicit content with mental imagery referring to a previous dream exists in the first two types, but the exactness of the details and contextual elements vary. In the third type, the content of the experience is not at the foreground, but the subject has the feeling of a known sensation or a state of consciousness similar to night dreaming. Only the first two types should be called déjà-rêvé, while the last type should be referred to as "dreamy state". We propose definitions for each type in Fig. 2.

It may be disputed that we cannot be sure that déjà-rêvé (episodic-like or familiarity-like) are linked to true previous dreams. EBS could simply produce a random combination of visual and auditory elements, creating phantasmagoric and unrealistic experiences similar to dreams. However, EBS-inducing déjà-rêvé were all located in the temporal lobes, although extratemporal brain areas were commonly stimulated [4]. They were also exclusively induced by medial temporal lobe EBS in our database. Thus, like other subtypes of experiential phenomena, specific locations of EBS seem to correlate with déjà-rêvé subtypes. This suggests it is improbable the déjà-rêvé we reported here are pure hallucinations, otherwise patients would have reported similar phenomena after stimulation of other brain areas. Furthermore, the brain regions implicated in déjà-rêvé include structures involved in long-term memory (especially in episodic memory and familiarity processes) [27–29], in memory formation during sleep [29], in normal dreaming [30,31] and probably in dream recall [32]. We also found a clear majority of right EBS in our database. We cannot draw conclusions from this because there are too few observations; however, right hemisphere activation during dream recall has already been suggested [33–37]. For example, the right hemisphere may be linked to dream materials and the left hemisphere to dream encoding and interpretation [34]. Lower alpha activity of the right temporal area has also been associated with successful recall of a dream [37]. Lastly, patients reporting a reminiscence after EBS are confident that it corresponds to true memories. There is no reason to think this should be different when they report dreams. Thus, it seems likely that déjà-rêvé ("episodic-like") corresponds to true dreams that are partly remembered after EBS. Following this interpretation, déjà-rêvé is similar to the recall of other reminiscences induced by EBS (detailed in [4]) but refers to the recall of exact content. Whether specific neurophysiological mechanisms underlie déjà-rêvé remains to be investigated. However, stimulation of the same contacts could induce either reminiscence of déjà-rêvé or reminiscence of other types of memories in some of our patients, suggesting a proximity between these types of memories.

These results emphasize the importance of detailed and suitable follow-up interviews of the patients to clarify the nature and content (affective, perceptual and mnemonic components) of the experiential phenomenon in all future studies and in routine clinical practice. This may explain in part why many phenomena from the literature were unclassifiable and why déjà-rêvé may have not been identified as such. There also appears to be some discrepancies in the types of classifiable phenomena, since the literature observations formed the bulk of the "dreamy state" subtype. This is likely a bias in our classification due to the simplification of the reports by many authors and the preponderance of Penfield's report in this category (he mainly stimulated the lateral part of the temporal lobes) [7,8]. In the literature, patient reports are often summed up in a few sentences and most of the time, the patient's follow-up interview has not determined exactly the type of déjà-rêvé. It is therefore possible that more episodic-like or semantic-like déjà-rêvé episodes were induced, but that due to the simplification of the reports, we classified them as "dreamy state". However, the fact that the dreamy state was the most common subtype in the literature may also not be an artifact: a meaningful difference in the type of the phenomena reported in literature *vs* our database is supported by the differences of EBS locations, which appear more diffuse and lateral for the dreamy-state subtype.

Better identification and definition of déjà-rêvé in epileptic patients may be relevant for clinical practice. It could guide neurologists when exploring temporal lobe dysfunction. EBS can induce déjà-rêvé in non-temporal epilepsy (as in patient 1 whose epileptogenic zone was frontal) but even in this case, EBS had to be in the temporal lobe. Our results thus suggest spontaneous déjà-rêvé may be specific to seizures involving the temporal lobes.

Furthermore, the qualitative nature of the déjà-rêvé seems to depend on the stimulation site, like we have previously demonstrated for other memories induced by EBS [4]. Separating déjà-rêvé from dreamy state could thus provide supplementary information as episodic-like déjà-rêvé points mostly to medial, rather than lateral, temporal lobes dysfunction. For instance, the report of an "episodic-like" déjà-rêvé as an aura of seizure should guide the neurologist towards an epileptogenic zone involving the medial temporal lobe. In contrast, a "dreamy state" (as defined in our classification) could point more generally to temporal lobe epilepsy. A majority of right EBS-inducing déjà-rêvé in our database could also suggest a potential lateralizing value of déjà-rêvé. But while this is consistent with fMRI results demonstrating that the recall of dreams and fantasies differentially activated a right hemisphere network [36], more data are needed to assess the strength of this hypothesis.

Nonetheless, EBS on the same site does not automatically replicate déjà-rêvé. The low prevalence of EBS inducing those phenomena suggests that a very particular combination of other—poorly understood—factors is required, including the technique used, electrical parameters, and maybe the baseline brain state at the moment EBS is applied. Future work should aim at improving our understanding of these factors.

Our classification and statistics are based on a small group, although this limitation can be attributed to the scarcity of déjà-rêvé induced by EBS. Often, the verbatim reports provided by authors were insufficient to allow correct classification, which increased the number of reports in the "unclassifiable" category. It is indeed notable that patient reports in the literature are usually summed up in a few words without any attempt to classify the reports using the taxonomy of the different types of memories that have been proposed [38]. Future studies should aim at providing more thorough reports, including precise stimulation parameters, to be more helpful for the study of memory.

Finally, EBS-induced déjà-rêvé could be an interesting approach to better understanding physiological dreams that cannot be reproduced under laboratory conditions. Understanding why some dreams can be remembered and decoding the mental content of dreams are great challenges. Most studies focus on REM (rapid-eye movements) sleep period [39] and dream reports obtained by awakening a sleeping subject [40]. However, non-REM sleep dreams account for a significant portion of all typical dreams and several factors might render dream reports less trustworthy—especially the sleep stage before awakening—when compared with reports of waking experience [40]. Analyzing intracranial EEG oscillations during induced déjà-rêvé could be an additional way to catch dreams by trapping EEG activity during this sudden, unexpected, and brief cognitive moment.

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Conflicts of interest

None of the authors has any conflict of interest to disclose.

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References

[1] Gloor P. Experiential phenomena of temporal lobe epilepsy. Brain 1990;113(6):1673–94.
[2] Ali F, Rickards H, Cavanna AE. The assessment of consciousness during partial seizures. Epilepsy Behav 2012;23(2):98–102. https://doi.org/10.1016/j.yebeh.2011.11.021.
[3] Illman NA, Butler CR, Souchay C, Moulin CJA. Déjà experiences in temporal lobe epilepsy. Epilepsy Res Treat 2012;2012:1–15. https://doi.org/10.1155/2012/539567.
[4] Curot J, Busigny T, Valton L, Denuelle M, Vignal JP, Maillard L, et al. Memory scrutinized through electrical brain stimulation: a review of 80 years of experiential phenomena. Neurosci Biobehav Rev 2017;78:161–77. https://doi.org/10.1016/j.neubiorev.2017.04.018.
[5] Van Buren JM. Sensory, motor and autonomic effects of medial temporal stimulation in man. J Neurosurg 1961;18:273–88.
[6] Neppe VM. The psychology of deja vu: have I been here before. Johannesburg: Witwatersrand University Press; 1983.
[7] Penfield W. Some mechanisms of consciousness discovered during electrical stimulation of the brain. Proc Natl Acad Sci U S A 1958;6:628–9.
[8] Penfield W, Perot P. The brain's record of auditory and visual experience. Brain 1963;86:596–695.
[9] Weingarten SM, Cherlow DG, Holmgren E. The relationship of hallucinations to the depth structures of the temporal lobe. Acta Neurochir 1977;24:199–216.
[10] Halgren E, Walter RD, Cherlow DG, Crandall PH. Mental phenomena evoked by electrical stimulation of the human hippocampal formation and amygdala. Brain 1978;101:83–117.
[11] Bancaud J, Brunet-Bourgin F, Chauvel P, Halgren E. Anatomical origin of deja vu and vivid "memories" in human temporal lobe epilepsy. Brain 1994;117:71–90. https://doi.org/10.1093/brain/117.1.71.
[12] Brown AS. A review of the déjà vu experience. Psychol Bull 2003;129:394–413. https://doi.org/10.1037/0033-2909.129.3.394.
[13] Vignal J-P, Maillard L, McGonigal A, Chauvel P. The dreamy state: hallucinations of autobiographic memory evoked by temporal lobe stimulations and seizures. Brain 2007;130:88–99. https://doi.org/10.1093/brain/awl329.
[14] Warren-Gash C, Zeman A. Is there anything distinctive about epileptic deja vu? J Neurol Neurosurg Psychiatry 2014;85:143–7. https://doi.org/10.1136/jnnp-2012-303520.
[15] Bartolomei F, Barbeau E, Gavaret M, Guye M, Mcgonigal A. Cortical stimulation study of the role of rhinal cortex in déjà vu and reminiscence of memories. Neurology 2004;63:858–64.
[16] Moulin C. The cognitive neuropsychology of déjà vu. New York: Routledge; 2017.
[17] Shelley PB. Speculations on metaphysics. In: The works of Percey Bysshe Shelley in verse and prose. London: Reeves & Turner; 1880. p. 297.
[18] Aragon L. Aurélien. Gallimard edition 1944. p. 37.
[19] Ferenczi S. A case of "déjà vu". In: Final contributions to the problems and methods of psychoanalysis. New York: Basic Books; 1955. p. 319–20.
[20] Fouillée A. Memory and recognition of memories. Revue des deux mondes 1885:131–62.
[21] Edgar Cayce's Association for Research and Enlightenment, https://www.edgarcayce.org/the-readings/esp-psychic-phenomena.
[22] Hughlings Jackson J, Colman WS. Case of epilepsy with tasting movements and 'dreamy-state'-very small patch off softening in the left uncinate gyrus. Brain 1898;21:580–90.
[23] Bartolomei F, Barbeau EJ, Nguyen T, McGonigal A, Régis J, Chauvel P, et al. Rhinal-hippocampal interactions during déjà vu. Clin Neurophysiol 2012;123:489–95. https://doi.org/10.1016/j.clinph.2011.08.012.
[24] Barbeau E, Wendling F, Régis J, Duncan R, Poncet M, Chauvel P, et al. Recollection of vivid memories after perirhinal region stimulations: synchronization in the theta range of spatially distributed brain areas. Neuropsychologia 2005;43:1329–37. https://doi.org/10.1016/j.neuropsychologia.2004.11.025.
[25] Talairach J, Bancaud J, Szickla G, Bonis A, Geier S. New approach to the neurosurgery of epilepsy. Stereotaxic methodology and therapeutic results. 1. Introduction and history. Neurochirurgie 1974;20:1–240.
[26] Xia M, Wang J, He Y. BrainNet viewer: a network visualization tool for human brain connectomics. PLoS One 2013:8. https://doi.org/10.1371/journal.pone.0068910.
[27] Moscovitch M, Nadel L, Winocur G, Gilboa A, Rosenbaum RS. The cognitive neuroscience of remote episodic, semantic and spatial memory. Curr Opin Neurobiol 2006;16:179–90. https://doi.org/10.1016/j.conb.2006.03.013.
[28] Barbeau EJ, Pariente J, Felician O, Puel M. Visual recognition memory: a double anatomo-functional dissociation. Hippocampus 2011;21:929–34. https://doi.org/10.1002/hipo.20848.
[29] Fell J, Fernández G, Lutz MT, Kockelmann E, Burr W, Schaller C, et al. Rhinal-hippocampal connectivity determines memory formation during sleep. Brain 2006;129:108–14. https://doi.org/10.1093/brain/awh647.
[30] Hobson JA, Pace-Schott EF. The cognitive neuroscience of sleep: neuronal systems, consciousness and learning. Nat Rev Neurosci 2002;3:679–93. https://doi.org/10.1038/nrn915.
[31] De Gennaro L, Cipolli C, Cherubini A, Assogna F, Cacciari C, Marzano C, et al. Amygdala and hippocampus volumetry and diffusivity in relation to dreaming. Hum Brain Mapp 2011;32:1458–70. https://doi.org/10.1002/hbm.21120.
[32] Bentes C, Costa J, Peralta R, Pires J, Sousa P, Paiva T. Dream recall frequency and content in patients with temporal lobe epilepsy. Epilepsia 2011;52:2022–7. https://doi.org/10.1111/j.1528-1167.2011.03290.x.
[33] Kerr NH, Foulkes D. Right hemispheric mediation of dream visualization: a case study. Cortex 1981;17:603–9.
[34] Doricchi F, Violani C. Dream recall in brain-damaged patients: a contribution to the neuropsychology of dreaming through a review of the literature. In: John S, Antrobus MB, editors. The neuropsychology of sleep and dreaming. Hillsdale, NJ: Erlbaum; 1992. p. 99–129.
[35] Stavitsky K, Mcnamara P, Ph D, Durso R, Harris E, Auerbach S, et al. Hallucinations, dreaming and frequent dozing in Parkinson's disease: impact of right-hemisphere neural networks. Cogn Behav Neurol 2009;21:143–9.
[36] Benedetti F, Poletti S, Radaelli D, Ranieri R, Genduso V, Cavallotti S, et al. Right hemisphere neural activations in the recall of waking fantasies and of dreams. J Sleep Res 2015;24:576–82. https://doi.org/10.1111/jsr.12299.
[37] Marzano C, Ferrara M, Mauro F, Moroni F, Gorgoni M, Tempesta D, et al. Recalling and forgetting dreams: theta and alpha oscillations during sleep predict subsequent dream recall. J Neurosci 2011;31:6674–83. https://doi.org/10.1523/JNEUROSCI.0412-11.2011.
[38] Tulving E. Organization of memory: quo vadis? In: Gazzaniga MS, editor. The cognitive neurosciences. Cambridge: MIT Press; 1995. p. 839–47.
[39] Hobson JA. REM sleep and dreaming: towards a theory of protoconsciousness. Nat Rev Neurosci 2009;10:803–13. https://doi.org/10.1038/nrn2716.
[40] Nir Y, Tononi G. Dreaming and the brain: from phenomenology to neurophysiology. Trends Cogn Sci 2010;14:88–100. https://doi.org/10.1016/j.tics.2009.12.001.

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