



Déjà vu in unilateral temporal-lobe epilepsy is associated with selective familiarity impairments on experimental tasks of recognition memory

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ABSTRACT

In déjà vu, a phenomenological impression of familiarity for the current visual environment is experienced with a sense that it should in fact not feel familiar. The fleeting nature of this phenomenon in daily life, and the difficulty in developing experimental paradigms to elicit it, has hindered progress in understanding déjà vu. Some neurological patients with temporal-lobe epilepsy (TLE) consistently experience déjà vu at the onset of their seizures. An investigation of such patients offers a unique opportunity to shed light on its possible underlying mechanisms. In the present study, we sought to determine whether unilateral TLE patients with déjà vu (TLE+) show a unique pattern of interictal memory deficits that selectively affect familiarity assessment. In Experiment 1, we employed a Remember-Know paradigm for categorized visual scenes and found evidence for impairments that were limited to familiarity-based responses. In Experiment 2, we administered an exclusion task for highly similar categorized visual scenes that placed both recognition processes in opposition. TLE+ patients again displayed recognition impairments, and these impairments spared their ability to engage recollective processes so as to counteract familiarity. The selective deficits we observed in TLE+ patients contrasted with the broader pattern of recognition-memory impairments that was present in a control group of unilateral patients without déjà vu (TLE−). MRI volumetry revealed that ipsilateral medial temporal structures were less broadly affected in TLE+ than in TLE− patients, with a trend for more focal volume reductions in the rhinal cortices of the TLE+ group. The current findings establish a first empirical link between déjà vu in TLE and processes of familiarity assessment, as defined and measured in current cognitive models. They also reveal a pattern of selectivity in recognition impairments that is rarely observed and, thus, of significant theoretical interest to the memory literature at large.

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1. Introduction

“It’s a really strange feeling. I’ll feel like I’ve been somewhere before – like I’m looking at a snapshot of a scene that I’ve seen previously. The strange bit is that I also know that I have not been to that place before.” (description of déjà vu from an individual in the current study).

Most people have been in a situation in which an environment suddenly feels strangely familiar, while also realizing they have never been in that specific place before. Such déjà vu experiences

have been defined in the psychological literature as “any subjectively inappropriate impression of familiarity of a present experience with an undefined past” (Brown, 2004; Nepppe, 1983). Critically, the impression of familiarity is experienced in association with a compelling sense that the current environment or situation should in fact not feel familiar. It is this incongruence that places déjà vu experiences among the most fascinating phenomenological expressions of human memory.

Despite extant coverage in current popular culture, déjà vu experiences remain poorly understood in scientific terms. Theories of the phenomenon that have been proposed in the psychological literature (see Brown, 2004, for review) are often appealing in an intuitive manner, but typically lack a foundation in empirical, controlled research evidence. Research progress has been hampered by the fleeting nature of the phenomenon in daily life, and by the lack of experimental paradigms to generate the

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phenomenon unambiguously in the laboratory. Although cognitive paradigms have been developed that can induce a false sense of familiarity (e.g., Brown & Marsh, 2009; Cleary, Ryals, & Nomi, 2009; Cleary et al., 2012), it remains challenging to determine whether this false familiarity is indeed experienced with the same compelling sense of inappropriateness that characterizes naturally occurring *déjà vu*.

In neurology, it is well established that a subset of individuals with temporal-lobe epilepsy (TLE) consistently experience *déjà vu* during the aura of their seizures (see Gloor, 1990, for review). In phenomenology, these experiences can be extremely compelling (e.g., O'Connor & Moulin, 2008) and appear to resemble the spontaneous *déjà vu* experiences reported by healthy individuals in many ways. Jackson and Colman (1898) were among the first to comment on *déjà vu* in TLE under the broader category of “dreamy state”, defined as an alteration of consciousness that is characterized by memory-like hallucinations, and/or a feeling of familiarity. Penfield (1954) later introduced the term “experiential phenomena” to describe altered subjective experiences, including those captured by the concept of “dreamy state”, that occur spontaneously at the onset of seizure discharge or can be evoked directly by intracranial cortical stimulation. It should be noted, however, that these broad terms cover a number of diverse subjective experiences with potentially distinct neural mechanisms, including *déjà vu*, *jamais vu*, flashbacks or reminiscences, and even hallucinations (Gloor, 1990). In clinical research on *déjà vu*, the diversity of phenomenology in mnemonic experiences has not always been fully considered (see O'Connor & Moulin, 2010, for discussion). This can, at least in part, explain why the reported incidence rate of ictal *déjà vu* in TLE varies substantially across published studies (Adachi, Akanuma, Ito, Adachi, & Takekawa, 2010; Cole & Zangwill, 1963; Gil-Nagel & Risinger, 1997; Gloor, Olivier, Quesney, Andermann, & Horowitz, 1982; Halgren, Walter, Cherlow, & Crandall, 1978; Pacia et al., 1996, van Paesschen, King, Duncan, & Connolly, 2001).

Modern epilepsy research on localization of mnemonic experiential phenomena in TLE has primarily linked them to the medial temporal lobes (MTL; Bancaud, Brunet-Bourgin, Chauvel, & Halgren, 1994; Gloor et al., 1982; Vignal, Maillard, McGonigal, & Chauvel, 2007; Weinand et al., 1994). There are findings obtained with intracranial EEG recordings, for example, showing that epileptiform activity associated with mnemonic experiential phenomena can be localized to medial rather than lateral temporal-lobe structures (Weinand et al., 1994; Vignal et al., 2007). Metabolic abnormalities, and evidence from cortical stimulation suggest, more specifically, that *déjà vu* in TLE may emerge from discharge in the anterior parahippocampal region (Bartolomei et al., 2004; Guedj, Aubert, McGonigal, Mundler, & Bartolomei, 2010; Takeda, Kurita, Sakurai, Shiga, Tamaki, & Koyama, 2011). For example, in a recent 18-FDG-Positron Emission Tomography investigation that compared lasting, interictal metabolic abnormalities in unilateral TLE patients with and without *déjà vu*, Guedj et al. (2010) noted more pronounced hypometabolism in ipsilateral rhinal cortices of those patients whose seizures were typically accompanied by *déjà vu*. Such findings raise the question as to whether unique interictal behavioral impairments may also be present. Curiously, this issue has received little empirical investigation in the neurological or neuropsychological literature so far (see Vederman, Holtzer, Zimmerman, Devinsky, & Barr, 2010 for recent negative findings with clinical neuropsychological tests).

The suggested link between *déjà vu* and rhinal-cortex regions in TLE is of particular interest in the context of the recent cognitive neuroscience literature on the role of the MTL in recognition memory. In many current models of recognition memory, a critical distinction is made between familiarity assessment and recollection (see Yonelinas, 2002, for review).

Familiarity assessment is a process that involves evaluating memory strength of an item independent from recovery of contextual detail about a specific past encounter. Although controversial, item familiarity has been proposed to depend specifically on computations performed in perirhinal cortex (PRc), and not in the hippocampus (see Aggleton & Brown, 1999; Eichenbaum, Yonelinas, & Ranganath, 2007; Norman, 2010; cf. Squire, Wixted, & Clark, 2007). Recollection, by contrast, involves direct recovery of contextual detail about a specific prior encounter with an item at the time of recognition; this process has been linked specifically to hippocampal functioning (see Montaldi & Mayes, 2010; Yonelinas, Aly, Wang, & Koen, 2010, for recent reviews). When considered within this model, part of the typical *déjà vu* experience in the aura of TLE can be characterized as a static sense of familiarity (e.g., Gloor, 1990; O'Connor & Moulin, 2008). Accordingly, the phenomenon may reflect, at its core, an erroneous familiarity signal that is generated by abnormal activity in PRc, or perhaps perirhinal- and entorhinal-cortex (see also Spatt, 2002). Preserved recollection and metacognitive inferences may produce the subjective sense of inappropriateness for this familiarity signal. Although not the topic of the current paper, we note that other mnemonic experiences in the aura of TLE seizures that are phenomenologically distinct from *déjà vu*, such as ‘*déjà vecu*’, are more dynamic in nature and may be tied more closely to false recollection (see Illman, Butler, Souchay, & Moulin, 2012 for discussion).

Considered together, the evidence reviewed hints that TLE patients who experience *déjà vu* in the aura of their seizures may present with lasting interictal behavioral impairments that are specific to familiarity assessment. That focal temporal-lobe lesions can produce impairments in familiarity assessment without affecting recollection has, to our knowledge, only been reported in a single case study so far. Bowles et al. (2007) observed this pattern in an individual (NB) who had undergone unilateral anterior temporal-lobe resection with hippocampal sparing as treatment for intractable TLE (see also Bowles, O'Neil, Mirsattari, Poppenk, & Köhler, 2011; Martin, Bowles, Mirsattari, & Köhler, 2011). Although NB was not tested pre-surgically with any experimental tasks of recognition memory, the fact that she experienced *déjà vu* as part of her seizures offers a further rationale for our hypothesis.

To determine whether the presence of ictal *déjà vu* in TLE is associated with selective interictal familiarity impairments, we compared a group of patients with intractable unilateral TLE who consistently experienced *déjà vu* as part of their seizures with another group of patients who did not. We administered two different experimental tasks to elucidate the specific nature of potential interictal recognition-memory impairments in the two groups of patients. Given that *déjà vu* in TLE (O'Connor & Moulin, 2008), as well as in healthy individuals (Brown, 2004), commonly extends to the entire immediate visual environment, we employed complex visual scenes as stimuli in both tasks. These scenes were sampled from a limited number of discrete categories (i.e., three types of rooms), however, so as to prevent memory discrimination based on gist and so as to encourage reliance on perceptual characteristics of objects that differed across scene exemplars. In the first task, a Remember-Know (RK) procedure (Tulving, 1985) was used to determine whether impairments in unilateral TLE with *déjà vu* would be selective for familiarity-based memory decisions and would spare those carried by recollection; like reports of *déjà vu* themselves, the RK procedure requires a subjective evaluation of the nature of recognition experiences. The second paradigm was an exclusion task administered to examine the interplay between both recognition processes under conditions in which they were placed in opposition experimentally (Jennings & Jacoby, 1997). Specifically,

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