

Exploring the Mechanisms of Déjà Vu: Neurological and Psychological Perspectives

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Abstract. Déjà vu, a French term meaning "already seen," refers to the perplexing sensation that a current experience has been encountered previously, despite a definitive lack of such an occurrence. This subjective feeling of familiarity, often accompanied by a simultaneous awareness that the familiarity is misplaced, affects approximately 60-70% of the population and is more prevalent in younger individuals, suggesting a potential link to developmental or cognitive processes. However, there is insufficient supporting evidence for the principle underlying the phenomenon. This report aims to explore the primary neurological and psychological theories that attempt to elucidate the underlying causes of this intriguing phenomenon, including disruptions in memory processing, transient neural activity, unconscious memory activation, and attentional influences. Furthermore, it briefly discusses the accessibility and limitations of current research approaches to study déjà vu, including frequency-based questionnaires and electroencephalography monitoring. Overall, this report provides a comprehensive overview of the current understanding of déjà vu and highlights the need for further research to unravel the complex interplay of factors contributing to this fascinating aspect of human consciousness and memory.

Keywords: Déjà vu; Memory; Temporal Lobe; Psychology; Neuroscience.

1. Introduction

The experience of déjà vu, the unsettling feeling of having already experienced a situation that is objectively new, is a common yet perplexing phenomenon that intrigues both scientists and the lay public. The formal study of déjà vu can be traced back to the late 19th century, with early psychological perspectives often linking it to memory distortions or subconscious recollections.[1] Over time, various theoretical frameworks have emerged, encompassing neurological, cognitive, and dual-processing explanations. Regarding its prevalence, déjà vu is a relatively common experience. Studies indicate that a significant proportion of the general population reports having experienced it at least once, with estimates ranging from 60% to 97% [2]. The frequency of déjà vu tends to be higher in younger individuals, particularly adolescents and young adults, and appears to decrease with age.

Understanding its origins requires delving into the complex interplay between memory processes and brain function. This paper aims to provide a comprehensive overview of the current understanding of déjà vu. It will explore the neurobiological structures implicated in memory and how their potential dysfunction might contribute to the experience. Additionally, key psychological frameworks, including dual-processing models of memory and theories involving unconscious memory activation like Gestalt familiarity, will be examined [3]. Furthermore, it will discuss ongoing controversies and alternative perspectives, such as memory monitoring theories and the potential role of attentional lapses. Finally, the methodological approaches currently employed in déjà vu research, including questionnaire-based studies and neuroimaging techniques, will also be reviewed [4, 5]. By synthesizing these different facets, this paper seeks to illuminate the multifaceted nature of déjà vu and highlight directions for future investigation into this fascinating aspect of human consciousness.

2. Neurobiological Foundations

Understanding the mechanisms behind déjà vu necessitates a brief overview of how the brain processes memories [1]. Several key brain regions are crucial for these processes.

2.1. Temporal Lobe Structures and Memory Processing

The temporal lobe, in general, plays a vital role in memory and sensory processing [1]. Within the temporal lobe, the medial temporal lobe (MTL) is particularly important for memory formation and retrieval. It encompasses key structures such as the hippocampus, parahippocampal gyrus, and rhinal cortex (including the entorhinal and perirhinal cortices). Notably, the parahippocampal gyrus and rhinal cortex play a key role in generating feelings of familiarity [2]. The hippocampus itself is primarily associated with recollection and the retrieval of contextual details. Early research by Wilder Penfield and Herbert Jasper involving electrical stimulation of the temporal lobe in epilepsy patients during surgery revealed that stimulation could evoke vivid memories and feelings of familiarity [3]. More recent studies using intracranial electrodes in Temporal Lobe Epilepsy (TLE) patients have further pinpointed the rhinal cortex (encompassing perirhinal and entorhinal cortex) as a key area whose stimulation is particularly likely to induce déjà vu and reminiscences [4]. This suggests that even subtle, non-pathological fluctuations in the activity of these temporal lobe structures could be responsible for the déjà vu experience in the general population [5].

2.2. Para hippocampal Cortex Dysfunction Hypothesis

One prominent theory centers on the idea that déjà vu results from a disruption in the normal coordination between the brain regions responsible for familiarity and recollection. From a neurological perspective, this phenomenon can manifest as an inappropriate or premature activation of the parahippocampal cortex, which is crucial for generating feelings of familiarity. This occurs without a corresponding activation of the hippocampus, which is necessary for the retrieval of specific memories. This decoupled processing leads to the sensation that the current situation is familiar, but without any accompanying memory of a prior encounter [6]. Erol Başar proposed a hypothesis suggesting that déjà vu arises from faulty and isolated activity of a recognition memory system which involves the parahippocampal gyrus and its neocortical connections responsible for familiarity judgments, while the hippocampal recall system remains unaffected. This hypothesis aligns well with the observation that during déjà vu, individuals often feel a strong sense of recognition for every detail of a scene, akin to comparing it to a photograph, yet they lack contextual memory or understanding of unseen aspects. The strong association between déjà vu and TLE has led to the hypothesis that transient neural disruptions in the temporal lobe might underlie the phenomenon even in healthy individuals. In TLE, déjà vu is often reported as part of the aura preceding a seizure, suggesting that abnormal electrical activity in the temporal lobe can trigger the feeling of familiarity [7]. While not indicative of epilepsy in most cases, it is theorized that similar, but much smaller and transient, neural misfiring or spontaneous activity in the medial temporal lobe could occur in healthy individuals, leading to a fleeting and inappropriate sense of familiarity.

3. Psychological Theoretical Frameworks

From a psychological standpoint, several frameworks attempt to explain the déjà vu experience.

3.1. Dual-Processing Model of Recognition Memory

The dual-process theory of recognition memory posits that recognition involves two distinct processes: familiarity and recollection [4]. Familiarity is a sense of knowing something without recalling specific details, while recollection involves the retrieval of contextual information associated with a past event. This theory suggests that déjà vu arises when the typically synchronized processes of familiarity and recollection become temporarily out of sync, leading to a feeling of familiarity in the absence of specific recall. Psychologically, this disruption can be conceptualized as

a slight asynchrony in the processing of sensory information [8]. The brain might process a scene or event along two pathways, with the pathway responsible for generating the feeling of familiarity being slightly faster than the pathway involved in detailed processing and contextual retrieval [9]. This temporal discrepancy could lead to the feeling of familiarity preceding the full conscious awareness of the novelty of the situation.

3.2. Gestalt Familiarity and Unconscious Memory Activation

Memory-based explanations propose that *déjà vu* occurs when a current situation bears subtle similarities to a past experience that is not consciously remembered, triggering a general sense of familiarity [10]. Another prominent psychological theory, supported by research including that of Anne Cleary and colleagues, proposes that *déjà vu* can arise when the spatial layout or configuration of elements in a new scene or environment is similar to that of a previously experienced scene stored in memory, even if that prior experience is not consciously recalled [11]. This is referred to as Gestalt familiarity, where the overall arrangement or "gestalt" of the environment evokes a sense of having been there before. The brain's pattern recognition systems might detect this similarity, triggering a feeling of familiarity without the retrieval of the specific memory of the prior scene. Neurologically, this process likely involves the parahippocampal gyrus, which plays a role in processing spatial information and contextual details. When a new environment shares a similar spatial configuration with a previously encoded one, the parahippocampal gyrus might activate familiarity signals. Research using virtual reality has provided empirical support for this hypothesis; studies have shown that participants are more likely to report feelings of *déjà vu* when they encounter a virtual scene that has the same spatial layout as a previously viewed scene, even if they do not explicitly remember the earlier scene. This work highlights that *déjà vu* can represent a mismatch between the brain's recognition and recollection systems [12] and suggests that even subtle, unconscious recognition of spatial similarities can contribute to the feeling of *déjà vu*. Furthermore, this feeling of familiarity can sometimes be accompanied by an illusory sense of prediction about what might happen next in the familiar-feeling environment.

Relatedly, *déjà vu* might also be triggered by the activation of memories that are not consciously accessible [13]. Individuals encounter countless pieces of information and have numerous experiences throughout their lives, many of which are not encoded with strong conscious awareness or are subsequently forgotten. However, these unconscious memories can still leave traces in the brain. If a current situation contains elements that resonate with these forgotten experiences, it could trigger a non-specific feeling of familiarity, leading to the sensation of *déjà vu*. This aligns with the "unrecalled memory hypothesis," where the feeling of familiarity stems from a genuine past experience that the individual cannot consciously bring to mind. For example, visiting a new city might evoke *déjà vu* if certain architectural details or street layouts unconsciously remind the person of places they saw in movies or pictures years ago, even if they don't explicitly recall those visual inputs at the moment.

4. Controversies and Alternative Perspectives

4.1. Memory Monitoring Theory vs. Cognitive Error

In contrast to theories that view *déjà vu* as a memory error, the memory monitoring theory, championed by researchers like Akira O'Connor, suggests that *déjà vu* might actually be a sign of a healthy and well-functioning memory system. According to this perspective, *déjà vu* occurs when the frontal regions of the brain, particularly the medial prefrontal cortex, detect a conflict between a feeling of familiarity generated by the temporal lobe and the actual absence of a corresponding memory. The frontal lobe, especially the medial prefrontal cortex, is involved in monitoring memory, detecting errors, and making decisions about the validity of memory signals. This "fact-checking" process results in the peculiar sensation of knowing something feels familiar but also knowing that this feeling is incorrect. O'Connor's research using functional Magnetic Resonance Imaging (fMRI)

has shown that during experimentally induced déjà vu, the medial prefrontal cortex, an area known for conflict detection, becomes active, while brain regions typically associated with memory retrieval do not [14]. This suggests that déjà vu arises not from a memory error itself, but from the brain's successful identification of a potential memory error. The feeling of déjà vu, in this view, is the conscious manifestation of the brain's memory monitoring system at work. This perspective could also explain why younger individuals, who tend to have more efficient memory monitoring abilities, experience déjà vu more frequently.

4.2. Attentional Lapse and Sensory Processing Theories

Another set of theories focuses on the role of attention in the déjà vu experience. Attentional theories suggest that brief lapses in attention or slight delays in processing sensory information can lead to a "double processing" of an event, creating the illusion of past experience. The attentional lapse theory posits that brief moments of inattention during the initial perception of a scene can lead to incomplete processing. When attention returns fully to the scene, the subsequent processing might feel like a re-experiencing of something already encountered, leading to déjà vu. A related idea is the split perception theory, which suggests that déjà vu can occur if a person experiences the current sensory input twice in quick succession [15]. The initial perception might be brief, degraded, or occur while the individual is distracted, resulting in a weak memory trace. The second, more complete processing of the same sensory information then triggers a feeling of familiarity due to the faint memory from the initial, less attentive perception. This theory implies that the feeling of "already seen" arises from the brain's interpretation of two closely spaced processing events as two separate experiences.

5. Methodological Approaches in Current Research

As the phenomenon tends to be associated with psychology and its detection must rely on conscious real-time feedback, direct experiments to assay the possible factors contributing to the déjà vu phenomenon require careful design. Noninvasive approaches are commonly undertaken. Hence, there are several possible plans for detection, including direct frequency inquiry and neuroimaging observation.

5.1. Frequency-Based Questionnaire Design

This approach aims to investigate the frequency of the déjà vu phenomenon among participants. This typically employs a questionnaire in which subjects are inquired about how often they encounter the déjà vu phenomenon and assess the frequency on a scale (e.g., from "never" to "quite frequently"). To be more specific, the questionnaire may also include open-ended questions about the conditions under which the déjà vu phenomenon typically takes place. Combining these methods can provide deeper insight into the subjective experiences of the participants. As current research has linked the déjà vu phenomenon with pathological conditions including seizure and TLE, to further improve research accuracy, a vivid and precise Déjà Vu Experiences Assessment should be arranged. Warren-Gash and Zeman proposed a practical triage system for evaluating patients with déjà vu, involving a stepwise approach to differential diagnosis [16]. First, clinicians should distinguish true déjà vu from related phenomena such as depersonalization, flashbacks, or colloquial usage of the term. Subsequently, patients can be categorized into three groups based on clinical features: First, those experiencing infrequent and transient episodes may be considered "probably normal." Second, cases accompanied by psychiatric symptoms, such as depression, anxiety, or psychosis, require further psychiatric evaluation. Third, episodes that are frequent, prolonged, or associated with physical sensations, automatisms, or seizures likely indicate TLE. This framework provides clinicians with a structured approach to guide further investigation and management.

5.2. EEG Imaging Observation

This approach utilizes electroencephalography (EEG) monitoring, a non-invasive technique that records the brain's electrical activity. This method detects and captures the electrical activity of

neuronal populations in the brain by placing electrodes on the scalp. P.N. Vlasov and his team, has compared EEG patterns during déjà vu in epileptic and non-epileptic subjects. Their research revealed differences in the neural mechanisms underlying déjà vu phenomena in these populations [17]. In healthy subjects, observed déjà vu episodes (lasting 10-15 seconds) exhibited only EEG rhythm desynchronization without epileptiform discharges, supporting their nature as a non-epileptic phenomenon. In sharp contrast, déjà vu episodes in epileptic patients were accompanied by significant abnormal discharges: A case study documented a post-traumatic epilepsy patient with right hemisphere dominance. During a 32-second déjà vu episode, the EEG displayed progressively developing epileptiform activity, including theta-band slow waves (with amplitudes reaching 200 μ V) and sharp waves. Dipole source localization identified the epileptic focus in the right medial temporal lobe and medial frontal lobe. Notably, such pathological episodes were often associated with autonomic responses (e.g., galvanic skin reactions) and negative emotional experiences, which markedly differed from the neutral or pleasant affective characteristics observed in healthy subjects.

However, this method has limitations. First, it has susceptibility to artifacts; movement (e.g., muscle activity), eye blinks, or environmental noise can corrupt EEG signals, requiring rigorous preprocessing. This is pertinent as déjà vu might be triggered by certain movements, potentially leading to errors in the outcome. Second, EEG provides excellent temporal resolution but has limited spatial resolution, making it challenging to precisely localize the neural sources of déjà vu within the brain. This spatial ambiguity can hinder efforts to pinpoint the specific brain regions or networks involved in the phenomenon, thus limiting the depth of insights that EEG alone can provide.

6. Conclusion and Future Directions

In summary, déjà vu is a multifaceted phenomenon with several potential underlying causes, spanning both neurological and psychological domains. These causes include disruptions in the dual processing of familiarity and recollection, transient neural activity in the temporal lobe, the unconscious recognition of similar spatial configurations (Gestalt familiarity), the brain's memory monitoring and error correction mechanisms, attentional lapses leading to a sense of repeated perception, and the activation of unconscious memories. While each of these theories offers valuable insights into the déjà vu experience, it is likely that the phenomenon results from a complex interplay between these various factors. Further research, utilizing both neuroimaging techniques like EEG and fMRI, alongside cognitive experiments and refined questionnaire methods, is crucial to deepen the understanding of this intriguing aspect of human consciousness and memory. Studying déjà vu not only helps to demystify this common experience but also provides valuable insights into the normal functioning and potential fallibility of the intricate memory systems of the human brain.

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