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# The relationship between working memory and episodic memory disorders in transient global amnesia

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**Abstract**

In a previous study, we investigated the relationship between the disorders of both episodic memory and working memory in the acute phase of transient global amnesia (TGA). Since executive functions were spared, another dysfunction may be responsible for the binding and maintenance of multimodal informations and contribute to the encoding disorders observed in some patients [Quinette, P., Guillery, B., Desgranges, B., de la Sayette, V., Viader, F., & Eustache, F. (2003). Working memory and executive functions in transient global amnesia. *Brain*, *126*, 1917–1934.]. The aim of this present study was to assess the functions of binding and maintenance of multimodal information during TGA and explore their involvement in episodic memory disorders. We therefore conducted a more thorough investigation of working memory in 16 new patients during the acute phase of TGA using two tasks designed to assess the binding process and both dimensions of the maintenance, namely the active storage and the memory load ability. We also investigated the nature of the episodic memory impairment in distinguishing between the performance of patients with preferential encoding deficits and those of patients with preferential storage disorders on the episodic memory task. This distinction was closely related to the severity of amnesia, i.e. an encoding disorder was observed rather in the early phase of TGA. The results showed that while the functions of binding and maintenance of multimodal information were intact in patients with storage disorders, they were impaired in the case of encoding deficits. These results are interpreted in the recent framework of episodic buffer proposed by Baddeley [Baddeley, A. D. (2000). The episodic buffer: A new component of working memory? *Trends in Cognitive Sciences*, 4, 417–423] that represents an interface between working memory and episodic memory.


*Keywords:* Transient global amnesia; Episodic memory; Binding process; Encoding; Phonological loop; Visuospatial sketchpad; Episodic buffer

## 1. Introduction

Transient global amnesia (TGA) is a clinical syndrome characterized by the abrupt onset of massive anterograde amnesia, usually accompanied by variable retrograde amnesia and repetitive questioning (Guillery et al., 2000; Hodges & Warlow, 1990; Quinette et al., 2006). As has been widely demonstrated by numerous neuropsychological studies, the memory impairment mainly concerns episodic memory, sparing other components such as procedural memory, priming effects and conceptual knowledge (Guillery et al., 2001; Hodges, 1994; Kapur, Abbott, Footitt, & Millar, 1996; Kazui & Tanabe, 1995). Concerning working memory (Baddeley, 1986), conclusions are more mixed. Most authors have made only a cursory assessment of this system, using common forward digit and visuospatial span tasks, and have concluded that the phonological loop and the visuospatial sketchpad are preserved. Even when one or two authors have used more complex tasks, involving the manipulation of information and/or executive processes, the results have been far from conclusive. Regarding the shifting process, while Goldenberg (1995) demonstrated impairment using a modified version of the Wisconsin Card Sorting Test (Berg, 1948; Goldenberg, 1995; Grant & Berg, 1948), Hodges (1994) failed to do so with the Trail Making Test (Reitan, 1958). Similarly, authors using the same version of the Stroop task (Stroop, 1935) have come up with contradictory results concerning inhibition (Hodges, 1994; Regard & Landis, 1984; Stillhard, Landis, Schiess, Regard, & Sialer, 1990).

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In a specially designed study, we investigated the main components of working memory during the acute phase of TGA (Quinette et al., 2003). We administered several working memory tasks to gauge the integrity of this system. Our assessment first focused on the central executive, the phonological loop and the visuospatial sketchpad, using the Brown-Peterson paradigm and both forward and backward digit and visuospatial span tasks. Second, in the light of Miyake et al.'s (2000) study, we tested the basic executive functions (inhibition, updating, shifting) using the Stroop test, the Running span task and the Trail Making Test, respectively. We also used a dual-task paradigm (Baddeley, Della Sala, Gray, Papagno, & Spinnler, 1997) to investigate the multi-tasking component, which is the primary major function attributed to the central executive and is thought to be independent of the others (Miyake et al., 2000). Except for pathological performances observed on the Brown-Peterson task for 3/3 patients during the episode, all the results were within the normal range of the age-matched control group. Thus, these results raised the question of the nature of the cognitive mechanisms involved in the Brown-Peterson task, which may depend not only on executive processes, but also on long-term memory. Moreover, because we made only an overall assessment of phonological loop abilities, we could not exclude the possibility that the pathological performances on the Brown-Peterson paradigm might also result from a deficit in short-term verbal storage.

At the same time, we investigated the anterograde amnesia by means of an episodic memory task, derived from Grober and Buschke's test (1987), differentiating the nature of the memory impairment that may refer to preferential encoding, storage and retrieval processes (see Eustache et al., 1999, for details). The encoding phase of the episodic memory task involved the semantic processing of a word list. Its effectiveness was checked by immediate cued recall performed every two words, while retrieval was assessed by means of free recall and recognition tasks. In this manner, we were able to identify two patterns of impairment, affecting either initial encoding (impaired immediate cued recall) or the storage of episodic events in long-term memory (pathological performances on both free recall and recognition tasks) previously reported in other studies of our group (Eustache et al., 1999; Guillery et al., 2000, 2001). Taken together, our results suggested that the executive functions, i.e. inhibition, updating and shifting, did not contribute to the episodic disorder. Since an episodic memory deficit may result from an impairment of an associative binding of separate components into compound episodes as demonstrated notably by Naveh-Benjamin et al. (Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Naveh-Benjamin, Guez, & Shulman, 2004), we speculated that the encoding deficit observed despite a successful deep processing resulted from this binding deficit that may operate at the initial stage of episodic learning.

Indeed episodic memory is comprised of collections of different features that are combined to form a coherent representation of an event. Consequently, creating new associations between the elementary features of an experience (e.g. colours, locations, time, objects, . . .) is critical for establishing episodic memories. This binding process may occur during the first stage of learning, namely during encoding (Johnson & Chalfonte, 1994). These authors have suggested that encoding, which determines storage efficiency, can be defined as the process by which information is maintained, manipulated and associated in working memory (Johnson, 1992).

Some studies have assessed the process of feature binding in working memory in the context of ageing, schizophrenia or amnesia. Hence, to find out whether the deleterious effect of ageing on episodic memory reflects binding deficits during initial encoding, Mitchell, Johnson, Raye, Mather, and D'Esposito (2000) examined memory for combinations of features in a working memory task. Participants were shown pictures of common objects in a $3 \times 3$ grid. They were asked to remember either the objects, the location of the pictures, or a combination of the two (object + location) after an unfilled 8 s interval. The authors reported that the older adults had lower difficulty in the ones than in the combination condition. In a second experiment, they demonstrated that even when older adults were influenced by the memory load (i.e. when they were tested on 2 features rather than 1), they still had an age-related binding deficit. On the basis of these results, the authors concluded that age-related deficits in the processes that mediate feature binding were manifested in the working memory task and might be responsible for long-term episodic memory disorders, namely for problems in establishing associations between episodic information, i.e. time, place and the modality of acquisition, at both the encoding and retrieval stages (Chalfonte & Johnson, 1996).

The same procedure was used in a more recent study of binding processes in patients with schizophrenia, using a working memory task (Burglen et al., 2004). The results of 25 patients were compared with those of 25 controls and showed that the processes which establish coherent and temporary episodic representations in working memory were impaired in schizophrenia. The authors hypothesized that the association of distinct features of an event needed in order to build a new multi-representation requires additional processes that go beyond the simple storage of individual features themselves. They suggested that the origin of the deficit in long-term memory observed in schizophrenia might be linked to difficulty in establishing associations between the different features of events.

Baddeley (Baddeley, 2000; Baddeley & Wilson, 2002; Baddeley, 2003a,b) proposed that working memory and episodic memory were related through an "episodic buffer". Using this component, he explained various results which did not fit his "classic model", notably correct immediate recall of prose in densely amnesic patients contrasting with poor performances on delayed recall (Baddeley & Wilson, 2002). These authors reported amnesic patients with an immediate memory span for sentences of about 15 or 16 words, while the equivalent span for unrelated words was typically about five items. Given that the difference could not result from a contribution of long-term memory in these amnesic patients, the authors postulated a further involvement of a binding process coordinated by working memory and particularly the episodic buffer, which would allow the correct recall of prose. According to Baddeley, the episodic