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The mechanisms of spontaneous and provoked confabulations

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Summary

Confabulation is a mysterious adjunct of amnesia. It remains unexplained why some patients invent untrue stories in response to questions (provoked confabulations) or even spontaneously with no apparent motivation (spontaneous confabulations). Hypothesized mechanisms range from a desire to fill gaps in memory to a loss of the temporal context in memory. We examined the mechanisms of confabulations in 16 amnesic patients. Patients were classified as spontaneous confabulators if they ever acted according to their confabulations. Provoked confabulations were measured as the number of intrusions in a verbal learning test. We found a double dissociation between the two types of confabulations, indicating that they represent different disorders rather than different degrees of the same disorder. Confabulating patients did not show an increased tendency to fill gaps in memory as measured by the number of fake questions concerning non-existent items that they answered. Neither type of confabulation correlated with a failure to store new information as gauged with recognition tasks; pure information storage was even found to be normal in some patients. However, we found a positive correlation between several measures of verbal learning and verbal fluency with provoked, but not spontaneous, confabulations. In contrast, spontaneous, but not provoked, confabulations were associated with an inability to recognize the temporal order of stored information as measured by the comparison of two runs of a continuous recognition task. We suggest that provoked confabulations depend on an amnesic subject's search in his deficient memory and are the trade-off for increased item recollection. Spontaneous confabulations appear to be based on a failure to recognize the temporal order of stored information, resulting in erroneous recollection of elements of memory that do not belong together.

Keywords: confabulation; amnesia; temporal order memory; frontal lobes

Abbreviation: CVLT = California Verbal Learning Test

Introduction

Confabulations have been defined as 'falsification of memory occurring in clear consciousness in association with an organically derived amnesia' (Berlyne, 1972). Many researchers distinguished between spontaneous (sustained, wide-ranging, grandiose, obvious in everyday conversation) and provoked (by questions probing memory) confabulations (Berlyne, 1972). It is not clear whether these types of confabulations represent different disorders (Van der Horst, 1932; Kopelman, 1987) or different degrees of a common disorder with spontaneous confabulations being the more severe type (Kapur and Coughlan, 1980; DeLuca and Cicerons, 1991; Dalla Barba, 1993; Fischer *et al.*, 1995). Several mechanisms of confabulations have been proposed. (i) Confabulations directly result from amnesia (Berlyne, 1972; American Psychiatric Association, 1994); but the severity of amnesia does not correlate with confabulations (Mercer *et al.*, 1977; Kapur and Coughlan, 1980). (ii) Confabulations reflect a desire to fill gaps in memory (Van der Horst, 1932; American Psychiatric Association, 1994); albeit plausible, this mechanism has never been formally explored. (iii) Confabulations arise from the combination of amnesia with a frontal dysexecutive syndrome (Mercer *et al.*, 1977; Stuss *et al.*, 1978; Shapiro *et al.*, 1981; Kopelman, 1987; Dalla Barba, 1993; DeLuca, 1993; Fischer *et al.*, 1995); but the dysexecutive syndrome represents a broad class of cognitive failures following prefrontal damage or disconnection (Sandson *et al.*, 1991), thus, this notion does not disclose the specific mechanism of confabulations.

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(iv) Confabulations reflect a loss of the temporal label of stored information. This mechanism was proposed for spontaneous confabulations a long time ago (Van der Horst, 1932) with no evidence, however, to support it.

We have recently studied a patient who, after sustaining an infarct of the right inferior capsular genu, could not recall previously learned information but produced abundant confabulations both spontaneously and in response to questions (Schnider *et al.*, 1996). In a series of experiments we demonstrated that she could store novel information normally, but failed to store the temporal order of information acquisition. This study thus indicated that confabulations were based on a failure to label new information temporally rather than a failure to store the information *per se*. The present study was undertaken in search of a common mechanism of confabulations irrespective of aetiology. In particular, we endeavoured to answer the following questions. (i) Are provoked and spontaneous confabulations different disorders or different degrees of the same disorder? (ii) Are confabulations associated with a desire to fill gaps in memory? (iii) Are confabulations dependent on an inability to store new information? (iv) Are confabulations due to a failure to recognize the temporal order of stored information?

Patients and methods

Sixteen patients with severe amnesia were asked to participate in the study. The diagnosis of amnesia was based on behavioural observation (all patients were hospitalized in our Division for Neuropsychological Rehabilitation at the time of the study) and formal memory tests. Data reported here from each patient were gathered within 1 week. Because all spontaneously confabulating patients (*see* definition below) had a delayed free recall ≤4 in the California Verbal Learning test (CVLT; Delis, 1987) only patients with equally impaired recall were finally included in the study. Inclusion criteria thus were: (i) delayed free recall ≤4 in the CVLT (Delis, 1987); (ii) digit span ≥5; (iii) no cognitive failure preventing participation in the experiments (e.g. aphasia, agnosia). Clinical characteristics and neuroradiological findings are listed in Table 1. Table 1 includes extended results of the CVLT, the late recall of the complex figure of Rey (1941) and performance on several frontal lobe tasks: verbal fluency (Thurstone and Thurstone, 1963), design fluency (Regard *et al.*, 1982) and colour–word interference (Stroop, 1935). All patients and control subjects gave informed consent to participate in this study.

Classification of confabulations

In previous studies authors often included features such as 'sustained, wide-ranging and grandiose' (Berlyne, 1972) or 'elaborate, extended' (Fisher *et al.*, 1995) in their definition of spontaneous confabulations, or classified 'severe' confabulations as spontaneous and 'moderate' confabulations as provoked (DeLuca and Cicerone, 1991). Such descriptions are arbitrary and are not necessarily correlated with the core feature of the two types of confabulations, namely, provoked or spontaneous (Kopelman, 1987). We distinguished between confabulations without implying any difference in severity or quality other than their being provoked or spontaneous.

Provoked confabulations were measured as the total number of intrusions in the CVLT (Delis *et al.*, 1987), i.e. the number of false words produced when recalling the word list. Healthy subjects produce very few intrusions in this test: 100 healthy controls, aged 44±16 years (19–79 years), made 1.7 (0–8, median 0.5) intrusions in all runs of this test (J. Ilmberger, unpublished data).

Spontaneous confabulations are more difficult to establish because an examiner can never be sure that he did not provoke a confabulation in some way. Confabulations that a patient produces truly spontaneously with no external trigger (supervision alone might be such a trigger) cannot be reliably quantified. For the purpose of this study we attempted to establish definitely the presence of, rather than to quantify, spontaneous confabulations. Based on observations by the examiners, other physicians and the nursing staff patients were classified as 'spontaneous confabulators' or 'other amnesic subjects'. A patient qualified as a 'spontaneous confabulator' if he ever acted upon his self-generated confabulations, a criterion which had been proposed by Berlyne (1972). For example, a patient explaining that he intended to give a speech to the parliament qualified as a spontaneous confabulator only if he ever took an active measure, e.g. packed his suitcase 'to go to the parliament'. Six patients qualified as spontaneous confabulators (Table 1).

It should be understood that this classification concerned only the presence or absence of spontaneous confabulations. Because spontaneous confabulations were not quantified, their mechanisms were examined by comparing spontaneous confabulators and other amnesic subjects. Irrespective of their producing spontaneous confabulations, all patients' production of provoked confabulations was measured. Because provoked confabulations were quantified, their mechanisms were examined with correlation analysis.

Cases

Patient 1 (spontaneous confabulator, no provoked confabulations)

This 58-year-old woman suffered subarachnoid haemorrhage from an anterior communicating artery aneurysm, which was clipped the next day. Postoperatively, she was confused and a severe memory disturbance was noted. A CT scan revealed a hypodense area involving the septum verum and the substantia innominata on both sides. She was transferred to our Neuropsychological Rehabilitation unit after 4 weeks. Memory testing revealed severe amnesia characterized by very deficient free recall and comparably preserved recognition (*see* Table 1 for neuropsychological results). She did not confabulate at all in memory tests and was usually

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Table 1 *Patient characteristics*

Patient/ sex/age	Aetiology*	Lesion site†	Days after onset	CVLT Run 5	CVLT Delayed recall	CVLT Recogn. Hits–FP‡	CVLT Intrusions sions	Rey Figure recall	Verbal fluency	Design fluency	Colour-word interf.	Associated findings
1/F/58	SAH (ACoA aneurysm)	Orbitofrontal	24	5	0	14–19	0	0	+++	+++	++	
2/M/45	Trauma	Left insula, right basal forebrain	45	6	2	11–4	26	10	++	++	+	
3/M/52	Trauma	Orbitofrontal	14	3	0	8–15	3	15	++	OK	+	
4/F/62	Infarction	Right capsular genu	210	9	4	12–7	65	9	OK	+	+	
5/M/45	Trauma (frontal contusions)	Bifrontal, extensive	87	3	0	11–15	12	0	+++	++	N/A	Roaming
6/M/67	Olfactory	Orbitofrontal meningioma	28	2	0	N/A	15	11	+++	OK	+	Anosmia, right oculomotor palsy
7/M/58	SAH (ACoA aneurysm)	Orbitofrontal	79	3	0	16–9	3	6	+++	+++	OK	
8/M/72	SAH (ACoA aneurysm)	Orbitofrontal	65	4	0	N/A	5	11	+	+++	OK	
9/F/53	SAH, spasms (right PCoA aneurysm)	Right fronto-parietal	136	5	0	10–11	11	N/A	OK	N/A	N/A	Left neglect and hemiplegia
10/M/55	Wernicke-Korsakoff synd.	(Medial thalamus)	150	7	1	10–3	10	6	++	++	+++	
11/M/57	Left paramedian thalamic infarct	Left medial thalamus	32	5	0	14–14	9	11	+++	+++	+++	
12/F/43	Multiple infarcts	Primarily right frontal	34	4	0	14–3	20	8.5	++	OK	+++	Talkativeness, distractability
13/F/18	Trauma	Medial temporal, right insula	270	4	0	12–14	4	2	++	++	OK	Gait ataxia
14/M/48	Cardiac arrest	(Hippocampus)	25	5	0	7–10	1	4.5	++	N/A	+	Depression
15/M/21	Trauma	Primarily mesencephalon	66	7	3	14–2	19	9	+	+	OK	Right hemiparesis
16/F/42	Trauma (shearing injury)	(Primarily mesencephalon)	69	11	4	16–10	37	14.5	OK	OK	OK	Diplopia, gait ataxia

Patient characteristics: the first six patients are spontaneous confabulators listed according to our clinical impression of the severity of confabulations (No. 1, severest). Provoked confabulations are listed as 'CVLT: intrusions' (controls, 1.0 ± 1.7) *Aetiology: SAH = subarachnoid haemorrhage; ACoA= anterior communicating artery; PCoA= posterior communicating artery. †Lesion sites are indicated as evident on CT or MRI scans or, in brackets, as presumed (the latter cases had normal MRIs). 'Orbitofrontal' designates lesions of the orbitofrontal cortex or basal forebrain. ‡Recognition indicated as hits – false positives (FP). Impairment of frontal executive functions: +++, severe; ++, moderate; +, mild. N/A = data not available.

astonished to hear that she had actually learned a list of words when asked for recall. She was active throughout the day but appeared to forget any instruction or plans told to her by the personnel. She confused people on the ward even after several weeks and never maintained temporal or spatial orientation. She did not have any insight into her memory failure. She confabulated floridly in conversation about plans she had for the day and about her stay in our house (she did not think that she was in a hospital); she thought she had several rooms there and would vividly explain how she had arranged them. She often acted according to her confabulations: she would step into another patient's room saying that it was her living room; she walked away from a test session telling the examiner that she had to watch her children who were playing on the terrace (all her children were adults by the time); she got up in the morning, packed her suitcase and went to a nurse to say goodbye, explaining that she had to look after her little boy who had not been fed yet. She regularly got upset when told that her children were grown up. Her amnesia, confabulations and disorientation did not improve and she was transferred to a closed unit after 4 months. This patient qualified as a 'spontaneous confabulator' because she spontaneously acted upon her confabulations, while she did not produce provoked confabulations according to our criteria.

Patient 2 (spontaneous confabulator also producing provoked confabulations)

This 45-year-old man suffered traumatic brain injury in an accident with his motorcycle. He remained unconscious for several hours. Repeated CT scans in the next days showed several haemorrhagic lesions, most notably in the right basal forebrain, beneath the left anterior insular cortex and in the rostral and posterior portion of the corpus callosum. He was transferred to our rehabilitation unit after 2 weeks. After an initial confusional period, his attention improved. He walked around on the ward, chatted with visitors and was considered a charming man. He was disoriented in time and place. The nurses noted that he was very forgetful about whatever they told him. Neuropsychological testing confirmed severe

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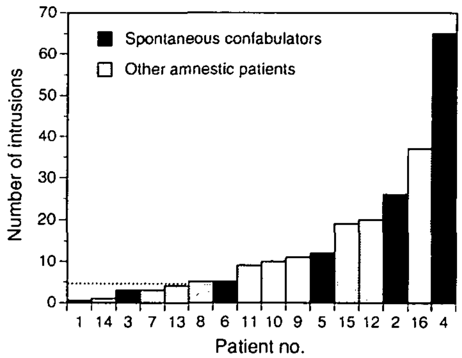

Fig. 1 Total number of intrusions in all runs of the CVLT (Delis *et al.*, 1987) as a quantitative measure of provoked confabulations. Patient numbers refer to Table 1. The dashed line in the lower left indicates the (mean+2 SDs) number of intrusions produced by 100 healthy controls.

amnesia. In tests of free recall he produced abundant confabulations (*see* Fig. 1) and appeared convinced that these words had actually been presented before. In conversation, he would tell true stories (confirmed by relatives) and entirely invented stories, which mostly related to his normal pastimes. He occasionally acted according to his confabulations. For example, he went to a physician's office and asked if he could use the telephone to arrange this afternoon's deer hunt with his friends. On another occasion he went to a physician to tell him that he was deeply concerned that he might not get a leave from military duties the next day. Although his confabulations did not have any 'grandiose' or 'elaborate' quality, the patient was classified as a 'spontaneous confabulator' because he occasionally acted according to his confabulations. Additionally, he produced many provoked confabulations in memory tests.

Patient 9 (provoked confabulations, no spontaneous confabulations)

This 53-year-old woman with a history of heavy alcohol consumption suffered subarachnoid haemorrhage from a right posterior communicating artery aneurysm, which was clipped. Postoperatively, spasms in the distribution of the right anterior and middle cerebral artery occurred, resulting in an infarct involving the right dorsolateral frontal and parietal lobe. CT additionally showed moderate cortical atrophy. On clinical examination, she had left hemiplegia and hemispatial neglect but no hemianopia. There was severe amnesia evident in everyday behaviour and on formal testing; she would regularly forget instructions by the personnel and would not know who had visited her. She was unconcerned about her memory failures and would play down any allusion to her bad memory. When asked questions concerning orientation she would not know the year and would fabricate a story to explain why the hospital had to be in another city than it actually was. When asked about her plans for the day, she would invent unrealistic activities, although it was never evident from her behaviour whether she actually believed what she said. However bizarre these stories were, she produced them only in response to questions and she never took any active measure to put her confabulated plans into effect. She was thus classified as an 'other amnesic patient'.

Patient 16 (massive provoked confabulations, no spontaneous confabulations)

This 42-year-old woman suffered a shearing injury of the brain when she was hit by a car. She was unconscious for some minutes. CT scan and MRI were normal. She had diplopia due to discrete left trochlear paresis (she preferred to have one eye covered for several weeks) and marked gait ataxia. She was fully oriented and was soon independent in her daily activities but she was very forgetful. In memory tests she achieved severely deficient scores both in free recall and in recognition tasks (many false positives). In free recall, she produced abundant confabulations which could mostly be traced back to items occurring in other tests, sometimes even tests that had taken place some days before. She never confabulated in conversation and never acted on any false beliefs. She was thus classified as an 'other amnesic patient'.

Experiment 1: filling gaps in memory

A desire to fill gaps in memory is a common interpretation of confabulations. Van der Horst (1932) introduced the term 'confabulations out of embarrassment' to designate what is now called provoked confabulations. He thus implied that patients who produce provoked confabulations have a sense of memory failure, but he left open the question as to whether confabulations represented a conscious or unconscious defence mechanism against embarrassment. DSM-IV (American Psychiatric Association, 1994), which does not distinguish between different forms of confabulations, assumes that confabulations are 'recitations of imaginary events to fill gaps in memory' (p. 157). We tested the tendency to fill gaps in memory with an experiment related to the test of suggestibility of Mercer *et al.* (1977). They asked patients a series of very difficult questions, to which most controls would respond 'I don't know'. In a second session, patients were again asked the questions to which they had previously responded 'I don't know' with the suggestive remark by the examiner that the patient had actually answered the question in the first run but that the examiner had forgotten to write down the answer. Mercer *et àl.* (1977) assumed that the patients really did not know the answer to these questions. They found no correlation between confabulations and the number of answered questions.

Our experiment was different in two main respects: (i) we did not make assumptions about a subject's knowledge about an item; rather we ensured that a subject had got a 'gap in memory' for the requested item; (ii) patients were not

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specifically motivated to invent a response to questions to which they did not know the answer.

We composed a questionnaire containing questions about existing items and fake questions about items that do not exist. For the latter items, subjects had to have a 'gap in memory'. The number of answered fake questions was used to measure the tendency to fill gaps in memory. The questionnaire comprised 30 questions: 15 questions concerned existing items, namely, five questions for each of three categories: famous personalities ('Who is Prince Charles?'); places ('Where is Los Angeles?) and relatively rare words ('What is a gazelle?'). Fifteen questions concerned non-existent items from the same three categories, e.g. 'Who is Princess Lolita?', 'Where is Prémont?', 'What is a water-cove?'. Patients were told by the examiner: 'I will ask you a number of questions. Answer them as well as you can'. The questionnaire was not given to one spontaneous confabulator (Patient 5). Twelve age- and education-matched control subjects were also given the questionnaire.

Experiment 2: information storage failure

With this experiment we investigated whether confabulations required an impairment of the capacity to store new information, i.e, whether patients had to have a 'gap in memory'. Tests of free recall, on which all our patients failed, are inappropriate to test pure information storage because they demand, in addition to information storage, additional cognitive steps, e.g. an active search in memory. Pure information storage is best represented by recognition tasks, which probe familiarity with previously met stimuli (Lezak, 1983). We used three continuous recognition tests with different types of stimuli: meaningful designs, nonsense geometric designs, and nonwords. In this type of task, subjects are shown a series of items, some of which (the target items) are repeatedly shown during the test, others (the distracter items) are presented only once. Such a task depends on long-term information storage if the number of items shown between subsequent presentations of a target item is beyond the capacity of the short-term memory, which is normally about six items (Hurst and Volpe, 1982; Sturm and Willmes, 1995). In the tasks used in this experiment, the average number of items between subsequent target presentations was 20.

We used different stimulus types because we suspected that confabulating patients might have particular difficulties with meaningful stimuli. The intrusions that the initial patient (Number 4) produced in memory tests were either items from previous tasks or semantically related to the stimuli which had actually been presented in the test. In continuous recognition tests involving nonwords and nonsense designs, i.e. stimuli with which she could not have an *a priori* sense of familiarity, her performance was normal. Hence the use of meaningful stimuli, which lend themselves to interference by previous experience, and meaningless stimuli, which are mandatorily novel.

The recognition tasks involving nonwords and nonsense designs were provided by Sturm and Willmes (1995). The meaningful designs recognition task was composed of pictures from Snodgrass and Vanderwart (1980). All three tasks had a similar design: they consisted of 120 stimuli, which were (unrecognizably for the test subject) composed of six series with 20 stimuli each. Each series contained eight stimuli that were repeated in all six series (i.e. they recurred five times) and 12 stimuli that were presented only once. Thus the tests contained 40 target items and 80 distracters, yielding a maximum score of 40 (40 hits, no false positive alarms). All stimuli were scanned into a Macintosh computer and presented for 2 s with an interstimulus interval of 0.7 s. Subjects were requested to answer for each stimulus the question: 'Have you already seen precisely this picture (or word) in this run?'. The examiner pressed the answer key on the computer. For the nonwords and nonsense designs recognition tasks, normal values from 450 healthy subjects were provided by Sturm and Willmes (1995). For the meaningful designs recognition test, control values were obtained from 10 age- and education-matched healthy subjects.

Experiment 3: temporal order recognition failure

In this experiment, we investigated whether confabulations were associated with a failure to recognize the temporal order of stored information. This capacity is difficult to test in amnesic subjects, however, because they fail to recall the information whose temporal label one intends to investigate. A common method to test memory for the temporal order of information acquisition requires patients to learn two lists of information some time apart. Then recognition of the target items is tested. Upon correct recognition of an item, the patient has to decide whether the item was in the first or second list (Squire *et al.*, 1981; Hurst and Volpe, 1982; Parkin and Hunkin, 1993). Such a task demands explicit recall of the temporal order of information presentation and thus risks underestimation of stored temporal order information.

We devised an experiment to test knowledge about the temporal order of information acquisition without demanding explicit knowledge of it. Because such a test requires that information has actually been stored, the easiest available memory task was used: the recognition test involving meaningful designs (Experiment 2). All amnesic patients had performed far above chance in this test [$P < 0.01$, $d' > 1.96$, determined with signal detection theory (Brophy, 1986)]. To probe temporal order recognition of stored information, subjects were again tested with the meaningful designs recognition task of Experiment 2 1 h after the first run. For the second run, the eight target items from the first run had been replaced by items that had been distracters in the first run. The eight target items from the first run were now

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among the distracters. All other parameters were identical to the first run. Subjects were instructed that they 'should forget' that they had already had a similar test and that they should only indicate the recurrence of an item in this very test run.

The idea behind the experiment was that a subject's false feeling that an item, which had actually been presented only in the first run so far, had already been presented in the second run (i.e. a false-positive alarm in the second run) was based on a failure to distinguish between the item's previous occurrence in the first rather than the second run (irrespective of whether it had been a target or a distracter in the first run); i.e. an increase of false-positive responses in the second run over the first run was presumed to indicate a temporal order recognition problem. In order to account for overall recognition performance and a tendency to say 'yes' rather than 'no' in case of uncertainty, the false-positive rate rather than the number of false-positives was analysed. Thus, the temporal order recognition failure was calculated as

$$(FP_2/hits_2) - (FP_1/hits_1)$$

with $FP_{1,2}$ = false-positive alarms in $run_{1,2}$ and $hits_{1,2}$ = true-positive alarms (hits) in $run_{1,2}$.

Results

Provoked versus spontaneous confabulations

As Fig. 1 shows, 11 patients produced more intrusions than normal controls (mean+2 SDs). If spontaneous confabulations simply represented the more severe form of confabulations, spontaneous confabulators should produce more provoked confabulations than other amnesic subjects. As Fig. 1 shows, this was not the case: spontaneous confabulators' production of provoked confabulations (intrusions) did not differ from the other amnesic subjects (Mann–Whitney *U* test: $U = 29$, $P = 0.9$). There was a double dissociation between the two types of confabulations (Fig. 1): Two spontaneous confabulators' (Patients 1 and 3) production of provoked confabulations was in the normal range, while several patients, who did not spontaneously confabulate (in particular, Patients 12, 15 and 16), produced massive provoked confabulations. These findings indicate that spontaneous and provoked confabulations are separate disorders rather than different degrees of the same disorder. For subsequent analyses, spontaneous confabulators and the other amnestic subjects were treated as distinct groups.

Filling gaps in memory (Experiment 1)

The three groups did not significantly differ from each other in their tendency to fill the type of memory gap examined in this experiment. Twelve controls answered 0.8±1.03 (median 0.5, range 0–3) fake questions, the spontaneous confabulators 3.2±3.9 (median 1, range 0–8) and the other amnesic subjects 1.1±2.0 (median 0, range 0–6; Kruskal–Wallis test, $H(2) = 1.2$, $P = 0.50$). Only three patients (two spontaneous confabulators, Patients 3 and 4; one other amnesic patient, Number 16) answered more fake questions than any control subject. Two spontaneous confabulators (Patients 2 and 6) and seven other amnesic subjects did not answer any fake question. Provoked confabulations did not significantly correlate with the number of answered fake questions (Spearman rank correlation $\rho = 0.16$, $P = 0.27$). These findings indicate that a desire to indiscriminately fill gaps in memory is not a common mechanism of either type of confabulation.

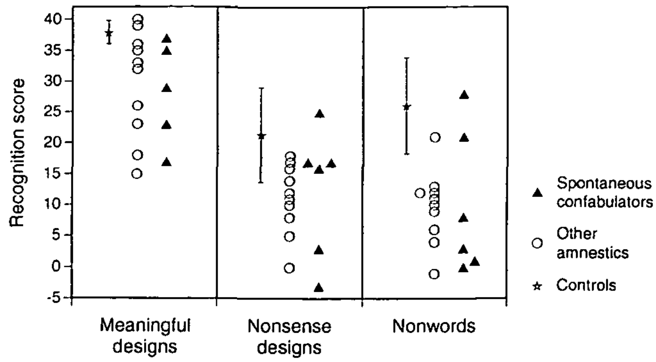

Fig. 2 Performance in the three continuous recognition tests (Experiment 2). Recognition scores are calculated as: hits–false positive alarms.

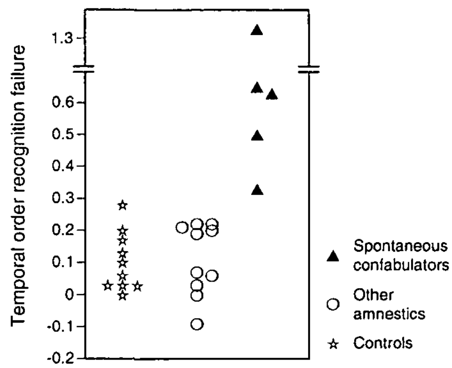

Fig. 3 Temporal order recognition failure (Experiment 3) measured as the increase of the relative number of false positives in the second run of the meaningful designs recognition test used in Experiment 2, i.e. $(FP_2/hits_2) - (FP_1/hits_1)$ with $FP_{1,2}$ = false positive alarms in $run_{1,2}$ and $hits_{1,2}$ = true positive alarms (hits) in $run_{1,2}$.

Information storage failure (Experiment 2)

Figure 2 summarizes the result demonstrating that (i) none of the three recognition tests distinguished between spontaneous confabulators and the other amnesic subjects (meaningful designs, $U = 22$, $P = 0.7$; nonsense designs, $U = 25$, $P = 0.6$; nonwords, $U = 26$, $P = 0.6$); (ii) several amnesic patients, including some spontaneous confabulators, performed in the normal range, i.e. mean ±1 SD of the controls and (iii) spontaneous confabulators' performance was not, as hypothesized, more selectively impaired with meaningful than with meaningless stimuli (Fig. 2).

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None of the recognition tasks significantly correlated with provoked confabulations (Spearman rank correlation: meaningful designs, $\rho = 0.25$, $P = 0.35$; nonsense designs, $\rho = 0.22$, $P = 0.40$; nonwords, $\rho = 0.31$, $P = 0.23$). Provoked confabulations also did not significantly correlate with false-positive alarms in the recognition tasks (meaningful designs, $\rho = 0.21$, $P = 0.45$; nonsense designs, $\rho = -0.02$, $P = 0.9$; nonwords, $\rho = 0.12$, $P = 0.65$). These results indicate that neither the occurrence, nor the severity, nor the type of confabulations depend on the severity of the failure to store new information as reflected by the performance in continuous recognition tasks.

Temporal order recognition failure (Experiment 3)

Figure 3 shows that this task clearly differentiated between spontaneous confabulators and all other test subjects (Kruskall–Wallis test: $H = 11.7$, $P = 0.003$): spontaneous confabulators had a higher increase of relative false-positives indicating failed temporal order recognition than both the 'other amnesic patients' (Mann–Whitney U test: $U = 0$, $P = 0.002$) and the controls ($U = 0$, $P = 0.002$), while amnesic patients who did not spontaneously confabulate, did not differ from control subjects ($U = 44$, $P = 0.65$). Although we did not test the correlation between the severity of the temporal order recognition failure and spontaneous confabulations (since spontaneous confabulations were not quantified), the result perfectly mirrors our clinical impression: the most severe spontaneous confabulators (Patients 1, 2 and 3) also had the highest increase of false positive responses in the second run, whereas the patient who just qualified as a spontaneous confabulator due to very occasional spontaneous confabulations (Patient 6) performed close to the other amnesic patients. Patient 4 (initial case) was not available when this experiment was devised but her failure to recognize the temporal order of stored information was demonstrated with a paradigm used by previous investigators (Squire *et al.*, 1981; Hurst and Volpe, 1982; Parkin and Hunkin, 1993): when presented with word pairs containing one word from a list she had learned 1 h before and another word from a list she had learned 2 h before, she completely failed to decide which word she had learned first. But she recognized these words among a series of distracters (Schnider *et al.*, 1996).

Provoked confabulations did not significantly correlate with the temporal order recognition failure ($\rho = -0.20$, $P = 0.45$).

Associations with the CVLT

Experiment 2 measured pure item storage. However, memory entails other components, e.g. a search in memory and retrieval of stored information. In order to account for memory functions in a broader sense than determined with Experiment 2, the association of confabulations with the performance in the CVLT was analysed. Spontaneous confabulators did not differ from the other amnesic patients on any of the analysed measures (Mann–Whitney U test, $P > 0.2$), i.e. total number of recalled words in the five learning trials, recall in the fifth learning trial, short-delay free recall, long-delay free recall, and long-delay recognition (hits – false positives).

In contrast, provoked confabulations significantly correlated with the recall in the fifth learning trial ($\rho = 0.50$, $P = 0.05$), long-delay free recall ($\rho = 0.76$, $P = 0.005$), and long-delay recognition (hits, $\rho = 0.76$, $P = 0.005$; false positives, $\rho = -0.61$, $P = 0.04$; hits–false positives, $\rho = 0.72$, $P = 0.01$). Thus, provoked confabulations are associated with relatively better performance in the CVLT.

Associations with frontal tasks

Table 1 shows that there was no consistent pattern of frontal impairment within and between the two patient groups. In order to test whether confabulations could be accounted for by the severity of frontal impairment, the association with the frontal tasks listed in Table 1 was examined, i.e. verbal fluency (number of correct words, number of perseverative and rule break errors; Thurstone and Thurstone, 1963), design fluency (number of correct designs, number of perseverative and rule break errors; Regard *et al.*, 1982), and Stroop colour–word interference (time in the interference run, errors in the interference run; Stroop, 1935).

Spontaneous confabulators did not significantly differ from the other amnesic subjects on any of these measures ($P > 0.5$ for all differences).

Provoked confabulations significantly correlated with the number of correct words produced in the verbal fluency task ($\rho = 0.51$, $P = 0.048$). No other significant correlations were present (design fluency: $\rho = 0.46$, $P = 0.09$; all other parameters: $|\rho| < 0.2$, $P > 0.4$). Because this result was entirely unexpected from the literature, in which it is suggested that frontal dysfunction gives rise to confabulations (Mercer *et al.*, 1977; Stuss *et al.*, 1978; Shapiro *et al.*, 1981; Kopelman, 1987; DeLuca, 1993; Fischer *et al.*, 1995), results from 12 additional patients (including one spontaneous confabulator) with a long-delay free recall ≤ 4 in the CVLT were included in the analysis. The correlation remained significant: intrusions correlated significantly only with the correct number of words produced in the verbal fluency task ($\rho = 0.56$, $P = 0.01$), not with the other measures ($P > 0.1$). Thus, among this population of amnesic subjects with frontal dysfunction, provoked confabulations were associated with relatively intact verbal fluency. No significant correlation between provoked confabulations and impaired frontal functions was found.

Because both verbal fluency and recall in the CVLT require an active search in memory, correlations with the CVLT were examined. Verbal fluency significantly correlated with the number of words recalled in the five learning trials ($\rho = 0.59$, $P = 0.02$), the fifth learning trial ($\rho = 0.70$, $P = 0.008$),

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and long-delay free recall ($\rho = 0.58$, $P = 0.03$), but not with measures of recognition. No other significant correlations were present.

Discussion

Our study reveals that spontaneous and provoked confabulations are different disorders with different mechanisms. Several authors suggested that spontaneous confabulations represent a severer degree of the same disorder as provoked confabulations (Kapur and Coughlan, 1980; DeLuca and Cicerone, 1991; Dalla Barba, 1993; Fischer *et al.*, 1995). The definitions of spontaneous confabulations applied in these studies included features like 'spectacular false memories' (Fischer *et al.*, 1995) or presumed that spontaneous confabulations were more severe than provoked confabulations (DeLuca and Cicerone, 1991; Dalla Barba, 1993). We distinguished between confabulations solely with regard to their being spontaneous or provoked without assuming any other qualifying feature. A patient was classified as a 'spontaneous confabulator' if he ever acted according to his confabulations, while provoked confabulations were measured as the total number of intrusions in the CVLT (Delis *et al.*, 1987). According to these criteria, spontaneous confabulators did not produce more provoked confabulations than other amnesic subjects, indicating that spontaneous confabulations are not simply 'more severe' than provoked confabulations. We found a double dissociation between spontaneous and provoked confabulations (Fig. 1): two spontaneous confabulators did not produce abnormal amounts of provoked confabulations and three of the five patients who produced the highest number of provoked confabulations did not spontaneously confabulate. Finally, the failure to recognize the temporal order of stored information (Experiment 3) clearly differentiated between spontaneous confabulators and other amnesic subjects but had no predictive value for provoked confabulations. These findings indicate that provoked and spontaneous confabulations are separate disorders that do not share a common mechanism.

Confabulations have been interpreted as representing a desire to 'fill gaps in memory', assuming that patients with memory impairment would fabricate a story to protect themselves from possible embarrassment (Van der Horst, 1932; American Psychiatric Association, 1994). We supposed that if confabulating patients did, in fact, have an abnormal tendency to fill gaps in memory, they should do so irrespective of the type of memory gap they experience. To test this, we devised a questionnaire containing questions about true items and fake questions about items that do not exist (Experiment 1); for the latter questions subjects had a mandatory 'gap in memory'. Our patients, including the spontaneous confabulators, did not answers significantly more fake questions than the controls, and provoked confabulations did not correlate with the number of answered fake questions. These results are in agreement with Mercer *et al.* (1977). They asked confabulating patients questions to which the patients had not known the answer in a previous session. This time, however, the examiners suggested to the patients that they had actually given an answer. They found that the tendency to produce an answer to these questions was not associated with the degree of confabulations. Our findings indicate that neither spontaneous nor provoked confabulations are associated with an indiscriminate tendency to fill gaps in memory.

Do confabulating patients actually have a gap in memory? Do they fail to store information? The performance of our initial patient (Patient 4) indicated that the amnesia associated with confabulations does not necessarily reflect deficient information storage; she performed normally in Sturm and Willmes's (1995) verbal and non-verbal learning tests (Schnider *et al.*, 1996). The demands imposed by these continuous recognition tasks are far beyond the capacity of the short-term memory (on average 20 items between subsequent presentations of a target item) and thus depend on long-term memory (Sturm and Willmes, 1995). Previous studies demonstrated normal performance of amnesic patients in some recognition tasks (Squire *et al.*, 1981; Hurst and Volpe, 1982; Squire and Shimamura, 1986; Parkin, 1992). It was suggested that the amnesic syndrome may not be appropriately characterized as a failure of registration or consolidation but may be based on an inability to suppress previous events, i.e. a failure of temporal order knowledge (Warrington and Weiskrantz, 1970; Hurst and Volpe, 1982; Parkin, 1992). Although continuous recognition tasks as used in our Experiment 2 may not measure the severity of amnesia appropriately (Squire and Shimamura, 1986), they may be the best measure of pure item information storage. We used three continuous recognition tasks to test whether confabulations were dependent on a failure to store information (Experiment 2). We found that performance in these tests did not have any predictive value for either type of confabulation: the spontaneous confabulators' performance was similar to the other amnesic patients; provoked confabulations did not correlate with the performance in these tests; some confabulating subjects, including some spontaneous confabulators, performed in the normal range. These findings indicate that confabulating patients need not fail to store new information; they need not have a 'gap in memory'.

The most tempting hypothesis was that all confabulations were based on a failure to recognize the temporal order of stored information. This mechanism was proposed by Van der Horst (1932) to explain spontaneous confabulations. We previously found deficient recognition of the temporal order of information acquisition in a case study of the initial patient of this series (Patient 4). In that study we used a temporal order recognition task described by earlier investigators (Squire *et al.*, 1981; Hurst and Volpe, 1982; Parkin and Hunkin, 1993): the patient was requested to indicate explicitly which of two words she had learned earlier that day. However, such an experiment hardly reflects the automatic temporal discriminations that constantly occur in memory; we rarely

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have to make conscious temporal discriminations. Experiment 3 tested the capacity to distinguish between separate events without explicit recollection of the temporal relation between them. Failure in this experiment was determined by active misjudgement (false-positive alarms) and indicated two things: (i) the subject did actually store information (the lag between the two test runs was 1 h); (ii) the subject failed to discriminate between temporally distinct presentations of information. We found that spontaneous confabulators, but not other amnesic subjects, failed to recognize the temporal order of stored information (Fig. 3). Conversely, provoked confabulations did not correlate with the temporal order recognition failure.

The results described so far do not disclose a mechanism for provoked confabulations: they do not appear to indicate a general tendency to fill gaps in memory (Experiment 1) and are not dependent on a failure to store information (Experiment 2) or to recognize the temporal order of stored information (Experiment 3). Contrary to our expectations (Mercer *et al.*, 1977; Stuss *et al.*, 1978; Shapiro *et al.*, 1981; Kopelman, 1987; DeLuca, 1993; Fischer *et al.*, 1995), we found that provoked confabulations positively correlated with relatively better verbal fluency and performance in the CVLT. Does this result indicate that relative preservation of memory and frontal functions are risk factors for provoked confabulations? This interpretation is implausible because it predicts that healthy subjects would produce the highest number of provoked confabulations. Both recall in a memory test and verbal fluency tasks demand an active search in memory. We suggest that provoked confabulations result from an amnesic subject's broad search in his deficient memory and are the trade-off for increased item recollection. Our study does not reveal the mechanism of this behaviour. We observed several times, however, that some amnesic patients produced provoked confabulations only in the initial memory tests, while others started to confabulate only after several months, an observation indicating that provoked confabulations may reflect a normal strategy to compensate for deficient memory rather than a stable psychopathological condition.

Our results do not support the idea of a causal link between confabulations and frontal executive failures (Stuss *et al.*, 1978; Kapur *et al.*, 1980; Shapiro *et al.*, 1981; Kopelman, 1987; DeLuca, 1993; Fischer *et al.*, 1995). Although most of our patients failed on several measures of frontal function, the pattern of impairments was heterogeneous (Table 1). Spontaneous confabulators did not differ from the other amnesic subjects on measures of frontal dysfunction. Previous studies postulating such a link did not define the types of confabulations as strictly as we did and were often limited to a single aetiology, usually haemorrhage from an anterior communicating artery aneurysm (Kapur *et al.*, 1980; DeLuca and Cicerone, 1991; DeLuca, 1993; Fischer *et al.*, 1995). They may thus have described variations of this particular disorder rather than variations of confabulations. Furthermore, the use of a composite 'frontal score' (Fischer *et al.*, 1995) may be appropriate to describe different degrees of a particular disorder but it risks concealing the specific cognitive components associated with confabulations.

Convergent evidence indicates that spontaneous confabulations are based on a specific frontal dysfunction, which is distinct from the commonly known executive failures. (i) Failed temporal order discrimination in memory, the type of impairment which sets our spontaneously confabulating patients apart from the other amnesic subjects (Experiment 3), was previously demonstrated in patients with prefrontal lesions (Milner *et al*, 1985; Shimamura *et al.*, 1991) and damage of the main relay station to this area, the dorsomedial thalamic nucleus (Shimamura and Squire, 1987; Hunkin and Parkin, 1993; Parkin *et al.*, 1994). These studies did not include patients with severe amnesia after orbitofrontal and basal forebrain lesions and described subtle deficits which were not associated with confabulations. (ii) Spontaneous confabulations have been reported in patients with orbitofrontal and basal forebrain damage (Alexander and Freedman, 1984; Damasio *et al.*, 1985; DeLuca and Cicerone, 1991; DeLuca, 1993) and lesions of the dorsomedial thalamic nucleus (Gentilini *et al.*, 1987; Victor *et al.*, 1989). In none of these patients was memory for the temporal order of events tested, however. Our Patient 4 suffered an isolated infarct of the right inferior capsular genu, a lesion disconnecting the dorsomedial nucleus from the orbitofrontal cortex as evident from severe atrophy of the anterior limb of the internal capsule revealed in the MRI. Two spontaneous confabulators (Patients 1 and 6) had focal orbitofrontal damage. We have previously suggested that temporal order recognition failure and confabulations are based on interruption of the loop connecting the orbitofrontal cortex directly and indirectly via the dorsomedial nucleus with the amygdala (Schnider *et al.*, 1996). In any instance, the available data indicate that spontaneous confabulations require damage or disconnection of prefrontal, probably orbitofrontal, areas and have an anatomical substrate that is clearly different from the amnesia ensuing from hippocampal lesions (Squire, 1992), which is characterized by severely deficient recognition and is not associated with spontaneous confabulations (Schnider *et al.*, 1994, 1995).

In conclusion, our study demonstrates that provoked and spontaneous confabulations are different disorders with different mechanisms. Provoked confabulations may be an amnesic patient's trade-off for increased recollection of information from his deficient memory. In contrast, spontaneous confabulations appear to be based on a failure to recognize the temporal order of stored information. It is conceivable that this disturbance leads to recollection of elements of memory that do not belong together, hence the production of false memories. Because spontaneous confabulations reflect a confusion of memory traces from diverse events rather than a lack of traces, they are not associated with a feeling of deficient memory. Patients thus behave on the basis of these erroneously composed memories

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just as healthy subjects' behaviour is guided by their correctly composed memories.

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