Patients who confabulate retrieve personal habits, repeated events or over-learned information and mistake them for actually experienced, specific unique events. Although some hypotheses favour a disruption of frontal/executive functions operating at retrieval, the respective involvement of encoding and retrieval processes in confabulation is still controversial. The present study sought to investigate experimentally the involvement of encoding and retrieval processes and the interference of over-learned information in the confabulation of Alzheimer’s disease patients. Twenty Alzheimer’s disease patients and 20 normal controls encoded and retrieved unknown stories, well-known fairy tales (e.g. Snow White) and modified well-known fairy tales (e.g. Little Red Riding Hood is not eaten by the wolf) under three experimental conditions: (i) full attention at encoding and at retrieval; (ii) divided attention at encoding (i.e. performing an attention demanding secondary task) and full attention at retrieval; (iii) full attention at encoding and divided attention at retrieval. We found that confabulations in Alzheimer’s disease patients were more frequent for the modified well-known fairy tales and when encoding was weakened by a concurrent secondary task (61%), compared with the other types of stories and experimental conditions. Confabulations in the modified fairy tales always consisted of elements of the original version of the fairy tale (e.g. Little Red Riding Hood is eaten by the wolf). This is the first experimental evidence showing that poor encoding and over-learned information are involved in confabulation in Alzheimer’s disease.

Keywords: Alzheimer’s disease; confabulation; memory; encoding; retrieval

Abbreviations: DA = divided attention; FA = full attention; NC = normal control; RT = reaction time

Introduction

The scientific study of human memory is largely based on the theoretical and experimental analysis of memory deficit in normal subjects and in amnesic patients. Memory deficit can express itself as ‘negative’ symptoms such as the failure to retrieve desired information, or as ‘positive’ symptoms such as memory distortions (Dalla Barba and Wong, 1995; Dalla Barba et al., 1995, 1999; Balota et al., 1999; Budson et al., 2000, 2002; Schacter and Slotnick, 2004). One such memory distortion is confabulation, that is the production of statements or actions that are unintentionally incongruous to the subject’s history, background, present and future situation (Dalla Barba, 1993a).

This rather infrequent disorder is classically described in Korsakoff’s syndrome (Korsakoff, 1889; Bonhoeffer, 1904; Wyke and Warrington, 1960; Talland, 1961; Mercer et al., 1977; Cermak et al., 1980; Dalla Barba et al., 1990; Benson et al., 1996; Schneider et al., 1996a). But confabulation is also
seen in patients suffering from ruptured aneurisms of the anterior communicating artery, subarachnoid haemorrhage or encephalitis (Luria, 1976; Stuss et al., 1978; Kapur and Coughlan, 1980; Alexander and Freedman, 1984; Moscovitch, 1989; Delbecq-Derouesné et al., 1990; De Luca and Cicerone, 1991; Irl et al., 1992; Kopelman et al., 1995; Moscovitch, 1995; Papagno and Muggia, 1996; Schneider et al., 1996a; Dalla Barba et al., 1997; Diamond et al., 1997), head injury (Weinstein and Lyerly, 1968; Baddeley and Wilson, 1986; Dalla Barba, 1993b; Schneider et al., 1996b; Demery et al., 2001), Binswanger’s encephalopathy (Dalla Barba, 1993a), Alzheimer’s disease and frontotemporal dementia (Kern et al., 1992; Dalla Barba et al., 1999; Nedjam et al., 2000, 2004) and aphasia (Sandson et al., 1993). Confabulation may also be observed, on occasion, in normal subjects (Kopelman, 1987; Burgess and Shallice, 1996; Dalla Barba et al., 2002).

Within confabulatory behaviour, a distinction has been proposed between ‘provoked’ and ‘spontaneous’ confabulation (Kopelman, 1987). According to Kopelman, provoked confabulation reflects a normal response to a faulty memory, whereas spontaneous confabulation reflects the production of an ‘incoherent and context-free retrieval of memories and associations’ (Kopelman, 1987, p. 1482) resulting from the superimposition of frontal dysfunction on an organic amnesia. For example, patients with spontaneous confabulation may report as personal memories incoherent and implausible events such as having been visiting their parents or grandparents who had been dead for years. Intrusion, the recall of unintentionally inappropriate information in a laboratory learning task such as word-list recall and story recall, has been considered a form of provoked confabulation (Kopelman, 1987). As far as story recall is concerned, both terms, intrusion and confabulation, have been employed to indicate the recall of inappropriate information (Kopelman, 1987; Dalla Barba et al., 2002; De Anna et al., 2008). We think that ‘intrusion’ more appropriately describes the production of unstudied words in word-list recall, whereas ‘confabulation’ better describes the production of unstudied information in story recall. Accordingly, in this study we will refer to confabulation as the production in a story recall task of a word or other story component that deviates at all from the original to-be-remembered story.

Clinical and experimental evidence shows that the content of confabulation consists of habits, repeated events or over-learned information mistakenly considered as specific unique episodes (Dalla Barba, 1993a; Dalla Barba et al., 1997, 1999; Burgess and McNeill, 1999). For example, when asked what they did the previous day, confabulating patients will often describe a habit from their daily life instead of remembering actual events. Although admitted to the hospital, they may say that on the previous day they went to work or they went out shopping, routines that were once part of their daily life. In addition to these uncontroversial observations, Dalla Barba and colleagues (De Anna et al., 2008) have experimentally shown that confabulations are made of over-learned information mistakenly considered as to-be-remembered material. They described the performance of a group of mild Alzheimer’s disease patients and a group of normal controls (NCs) on the recall of three different types of stories: a previously unknown story, a well-known fairy tale (Cinderella) and a modified well-known fairy tale, that is, a well-known fairy tale in which the semantic structure is modified so that the whole meaning of the story changes, e.g. Little Red Riding Hood makes friends with the wolf. They found that Alzheimer’s disease patients produced significantly more confabulations in the recall of the modified fairy tale compared with the recall of the two other stories. Confabulations in the recall of the modified fairy tale always consisted of elements of the original version of the story, i.e. subjects tended to say that the wolf ate Little Red Riding Hood. Accordingly, they concluded that in Alzheimer’s disease patient’s confabulations reflect the interference of strongly represented over-learned information in episodic memory recall.

An important question about confabulation is how its production is influenced by encoding and retrieval processes. A hypothesis of disruption of frontal/executive processes operating at retrieval has been proposed, based on studies of brain-damaged patients. This hypothesis predicts that executive processes are crucial for monitoring the retrieval of information from long-term memory and that confabulation reflects defective monitoring (Moscovitch, 1989; Johnson, 1991; Moscovitch, 1995; Burgess and Shallice, 1996; Schneider et al., 1996b; Moscovitch and Melo, 1997). Numerous lines of neuropsychological evidence have highlighted the prefrontal cortex as the likely culprit in causing confabulation (Baddeley and Wilson, 1986; Fischer et al., 1995; Schneider et al., 1996b; Moscovitch and Melo, 1997). For example, perseveration has been observed in confabulation, and this evidence has been used to promote the role of executive dysfunction in confabulation (Kopelman et al., 1997). Indirect evidence supporting the retrieval deficit account of confabulation is provided by the fact that patients often confabulate even when they are required to retrieve pre-morbid memories, that is, memories from a life period when encoding was presumably unaffected. However, it has been argued (Dalla Barba et al., 1998, 2002; De Anna et al., 2008) that confabulation may reflect the interaction between impaired retrieval and shallow encoding (Craik and Tulving, 1975). This hypothesis is based on the evidence that confabulation may affect recent, post- and pre-morbid memories more than remote memories (Dalla Barba et al., 1998).

Using a divided attention (DA) paradigm, it has been shown that performing a secondary task during encoding reduces later memory performance, whereas performing a secondary task during retrieval has little or no effect on memory performance (Baddeley et al., 1984). Retrieval processes, however, do not proceed without attentional resources but are shown to have an ‘attentional cost’, since DA at retrieval results in a large increase of reaction time (RT) in the secondary task (Craik et al., 1996; Anderson et al., 1998; Naveh-Benjamin et al., 1998). Normal subjects are also known to make more memory distortions when a secondary task is performed during the encoding than when it is performed during the retrieval (Dalla Barba et al., 2002), but the influence of DA on confabulations at encoding and at retrieval in patients with memory disorders has not yet been experimentally explored.
In line with our previous work, in this study, we hypothesized that in Alzheimer’s disease patients over-learned information interferes with the recall of specific, unique past episodes; and this interference should be more prominent when a concurrent task perturbs the encoding of the episodes to be recalled. We tested this hypothesis using an experimental paradigm aimed at eliciting confabulations. We asked Alzheimer’s disease patients and NCs to recall different types of stories: three unknown stories [similar to the Logical Memory test in the Wechsler Memory Scale-Revised, (Wechsler, 1987)], three well-known fairy tales (e.g. Snow White) and three ‘modified’ well-known fairy tales (Little Red Riding Hood makes friends with the wolf). Each type of story was presented and recalled under three experimental conditions: (i) full attention (FA) at encoding and at retrieval; (ii) DA at encoding and FA at retrieval; (iii) FA at encoding and DA at retrieval. According to the above hypothesis, subjects should produce more confabulations for the modified well-known fairy tales than for the other types of stories because original, over-learned information concerning the fairy tale interferes with the recall of its modified version. It was further predicted that DA at encoding should lead to a larger number of confabulations compared with the other two experimental conditions.

Materials and Methods

Participants

A total of 40 subjects participated in the study. Twenty patients with a clinical diagnosis of probable Alzheimer’s disease according to the criteria of the Diagnostic and Statistical Manual of Mental Disorders (American Psychiatric Association, 1994), National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer’s Disease and Related Disorders Association (McKhann et al., 1984) (14 female, mean age: 78.4 years, range: 73–84 years; years of education: 9.8, range: 8–12, all right-handed), and 20 aged NCs (12 female, mean age 76.4 years, range 72–84 years; years of education: 10.2, range: 8–16, all right handed). Alzheimer’s disease patients and NCs did not differ significantly in terms of age \[F(1,38) = 2.9, P = 0.09\] and years of education \(F(1,38) = 0.5, P = 0.4\). Alzheimer’s disease patients and NCs differed significantly in terms of Mini Mental State Examination (Folstein et al., 1975) scores \(\text{mean: 22.7, range: 21–24 and mean: 28.2, range: 27–30, for Alzheimer’s disease patients and NCs, respectively, } F(1,38) = 193.5, P < 0.0001\). Alzheimer’s disease patients had a digit span \(\geq 5\) and were judged to be normal on bedside tests of oral expression and understanding of oral language.

Patients with potentially confounding neurological and psychiatric disorders, clinically known hearing or vision impairment, a past history of alcohol abuse, psychosis or major depression were excluded. The use of medication that could interfere with test performance or diagnosis was considered as further exclusion criteria. NCs were either spouses of patients or other individuals who volunteered to participate in the research projects of our laboratory. All the participants gave their written informed consent. The study was conducted in accordance with the ethical standards laid down in the Declaration of Helsinki (2000).

Experimental material

Memory tasks

Nine short stories were used in this experiment: (i) three unknown stories, (two adapted from the Logical Memory subtest of the Wechsler Memory Scale-Revised (Wechsler, 1987) and one adapted from Barbizet’s Lion Story (Barbizet and Truscelli, 1965)); (ii) three well-known fairy tales (Snow White, Three Little Pigs and Goldilocks and the Three Bears); and (iii) three ‘modified’ well-known fairy tales (Little Red Riding Hood, Cinderella and Tom Thumb). In the latter stories, the sense of the original story was completely changed, for example, Little Red Riding Hood is not eaten by the wolf. Each story was composed of 35 to-be-remembered elements. In the unknown stories, 10 to-be-remembered elements were added to the two stories of the Logical Memory subtest of the Wechsler Memory Scale-Revised (Wechsler, 1987). For example, some added elements were: /Anne Boiron/could pay/ a meal to her children. Across stories, the to-be-remembered elements were comparable in terms of length, emotional content and amount of perceptual details.

RT task

This task involved a visual display on a computer screen and manual responses on the computer keyboard. The display consisted of one box located in the centre of the screen. An asterisk appeared in the box every 500, 1000 or 1500 ms, and the task was to press as quickly as possible the space bar on the keyboard when the asterisk appeared. A correct response caused the asterisk to disappear; the asterisk did not disappear until the correct key was pressed, and therefore no errors were recorded. RTs were recorded by the computer.

Procedure and design

We used a within-subjects design with all participants performing all tasks. Participants were first given a practice trial on the RT task for 60 s. They were then asked to encode and retrieve the three types of stories under three different experimental conditions: (i) free encoding and free retrieval (free–free); (ii) RT at encoding and free retrieval (DA–free); and (iii) free encoding and RT at retrieval (free–DA). The types of stories and the experimental conditions were counterbalanced according to the Latin Square. In the free–free condition, participants were read aloud by the experimenter one story of each type and instructed that they would be tested for recall immediately after the presentation. After the presentation, which lasted ~60 s, the subjects were required to free recall as many elements as they could of the story they had just heard. They were allowed 120 s for the recall. The subjects’ recall was tape-recorded and subsequently scored by three different raters according to the number of elements correctly recalled and the number of confabulations. Inter-raters’ reliability was 100%. Confabulation was defined as the production of elements that deviate in any way from the original to-be-remembered material. For example, in the report ‘Anne Boiron...working as a teacher...’ the word ‘teacher’ was considered a confabulation since it deviates clearly from the to-be-remembered element ‘Anne Boiron...working as a cook...’. In the DA–free condition, subjects were read aloud one story of each type while performing the RT task. Immediately after the presentation of each story, the subjects were asked to free recall as many elements as they could of the story they had just heard. The scoring procedure was the same as in the free–free condition. In the free–DA condition, subjects were read aloud one story of each type and then asked for a free recall of the story they just heard while performing the RT task.
Statistical analyses were conducted on RT, on the number of elements recalled, and on the ratios of correct responses and of confabulations over the total number of elements recalled. The rationale for this latter analysis was to know whether patients produced more confabulations than correct responses. In other words, a subject may recall only a few elements of the to-be-remembered story, but most, or all of these elements may be confabulations. This data are much more informative about the tendency to produce confabulations than is the total number of confabulations alone.

Results

Total recall

Alzheimer’s disease patients, compared with NCs, showed consistently a lower total recall, that is the sum of correct responses and confabulations for all types of stories and in any experimental condition (Fig. 1). The total number of elements recalled for the three types of stories in the three experimental conditions were entered in a three-way analysis of variance (ANOVA) with group (Alzheimer’s disease versus NC) as between-subjects factor and type of story (unknown stories versus well-known fairy tales versus modified well-known fairy tales) and attentional condition (FA versus DA at encoding versus DA at retrieval) as repeated measures factors. Results indicated a main effect for group \[F(1,38)=58.2, P<0.0001\], for type of story \[F(1,2)=39.9, P<0.0001\] and for attentional condition \[F(1,2)=15.4, P<0.0001\]. Post hoc analysis (Scheffe’s F-corrected for multiple non-independent comparisons) revealed that Alzheimer’s disease patients recalled significantly fewer elements than NCs in all experimental conditions (all \(P<0.0001\)).

Significant interactions were observed for group by type of story \[F(1,2)=9.4, P<0.0001\], group by attentional condition \[F(1,2)=3.4, P<0.05\] and group by type of story by attentional condition \[F(1,152)=2.6, P<0.05\]. These interactions indicate that, in the two groups of subjects, total recall is affected differentially by the type of story and attentional conditions.

Varying attentional conditions had no effect on Alzheimer’s disease patients but it did have an effect on NCs, who recalled significantly fewer elements in the DA at encoding condition of the unknown stories and the modified well-known fairy tales (all \(P<0.01\)).

The type of story influenced total recall less in Alzheimer’s disease patients than in NCs. Alzheimer’s disease patients recalled significantly fewer elements of the unknown stories in the DA at retrieval condition than elements of the well-known fairy tales and of the modified well-known fairy tales in the corresponding conditions (both \(P<0.05\)). They also recalled more elements of the well-known fairy tales in the FA and in the DA at retrieval conditions than elements of the modified well-known fairy tales in the corresponding conditions (all \(P<0.05\)). NCs recalled significantly more elements of the well-known fairy tales in each of the three experimental conditions than elements of the other types of story in the corresponding conditions (all \(P<0.0001\)).

Percentage of correct responses and confabulations

As reported in the Materials and methods section, statistical analysis was conducted on the percentage of correct responses and confabulations (see the Materials and methods section for the rationale of this analysis).

Alzheimer’s disease patients consistently produced a lower percentage of correct responses and a larger percentage of confabulations (Fig. 2) than NCs for all types of stories and in all experimental conditions.

The percentage of correct responses and confabulations were entered in a \(2 \times 3 \times 2\) ANOVA with group (Alzheimer’s disease versus NC) as between-subjects factor and type of story (unknown stories versus well-known fairy tales versus modified well-known fairy tales), attentional condition (FA versus DA at encoding versus DA at retrieval) and type of response (correct responses versus
The analysis of performance within each type of story showed that both Alzheimer’s disease patients and NCs produced a significantly lower percentage of correct responses and a higher percentage of confabulations in the DA at encoding condition of the modified well-known fairy tales compared with the two other conditions (all \( P<0.005 \)). No significant difference emerged for the other types of stories. In other words, the detrimental effect of interference at encoding emerges only when the to-be-remembered material, but consistent with the semantic structure of the story. An example of confabulation in the recall of the unknown stories is reported in the Materials and methods section. In the recall of the well-known fairy tales, several patients reported, for example, that ‘Cinderella was beautiful’, an element which did not belong to the to-be-remembered material, but was consistent with the ‘traditional telling’ of this tale.

In the modified fairy tale condition, Alzheimer’s disease patients’ confabulations always consisted of elements of the original version of the story. The following is an example of the modified version of the Little Red Riding Hood fairy tale read by the examiner to the patient: ‘Once upon a time there was a little girl called Little Red Riding Hood because of her little red hood. On her way to visit her grandmother, Little Red Riding Hood found a nice wolf cub lost in the forest. Little Red Riding Hood decided to take the wolf cub to her grandmother’s to feed it. Very scared, the grandmother implored Little Red Riding Hood to put the animal back in its den. Little Red Riding Hood was very sad when she left her grandmother’s house with the wolf cub, but then, fortunately, in a clearing of the forest she found the mother wolf.’ This narration was recounted in the following way by one Alzheimer’s disease patient: ‘Once upon a time there was a little girl called Little Red Riding Hood because she was wearing a red hood. She goes in the forest and there she encounters the wolf. But the wolf doesn’t eat Little Red Riding Hood… not immediately. Little Red Riding Hood takes the wolf to her grandmother’s and there the wolf eats Little Red Riding Hood. It ends like that. But there is something in between… I can’t remember…’ As it emerges from this example, the original version of the story clearly interferes with the recall of its modified version. In other words, strongly represented, over-learned information interferes with episodic recall, even though some episodic elements are present in the patient’s report (e.g., Little Red Riding Hood takes the wolf to her grandmother’s house).

The RT

Mean values for the RT tasks are shown in Fig. 3. Alzheimer’s disease patients showed higher RT than NCs in all conditions. Subjects’ performance on RT tasks during encoding and retrieval of the three types of story were entered in a three-way ANOVA

Correlation analysis

On both NCs and Alzheimer’s disease patients, correlation coefficients were calculated between confabulations and correct responses for the three types of stories and in the three experimental conditions. Significant, negative correlations were observed in all conditions and for all types of to-be-remembered material (all \( P<0.01 \)).

Correlation coefficients were also calculated between responses (correct and confabulations) and RT. Significant, negative correlations were found for correct responses in both DA at encoding and DA at retrieval for the three types of story (all \( \rho >-0.35 \); all \( P<0.01 \)). A significant, positive correlation was also found for confabulations in the DA at retrieval condition of the well-known fairy tales (\( \rho=0.45; P<0.01 \)).
significantly RT compared with RT performed alone (all DA during the encoding of the three types of stories did not affect RT compared with RT performed alone (all retrieval was associated with a larger and significant increase in P of RT for unknown stories and well-known fairy tales (both alone, DA at encoding was associated with a significant increase differently by the type of story and the memory condition.

Results indicated a main effect for group [F(1,38) = 54.9, P < 0.0001], for type of story [F(1,2) = 3.4, P < 0.05] and for memory condition [F(1,1) = 251.4, P < 0.0001]. Post hoc analysis (Scheffe’s F-corrected for multiple non-independent comparisons) revealed significantly higher RT in Alzheimer’s disease patients compared with NCs in any experimental condition (all P < 0.0001). These results are consistent with previous data showing a general decrement of attentional resources in Alzheimer’s disease. They also show that both the type of to-be-remembered material and the memory condition (encoding versus retrieval) affect RT.

Significant interactions were observed for group by memory condition [F(1,1) = 39.6, P < 0.0001], type of story by memory condition [F(2,2) = 5.8, P < 0.01] and group by type of story by memory condition [F(1,76) = 6.5, P < 0.01]. These interactions indicate that, in the two groups of subjects, RTs are affected differentially by the type of story and the memory condition.

In Alzheimer’s disease patients, compared with RT performed alone, DA at encoding was associated with a significant increase of RT for unknown stories and well-known fairy tales (both P < 0.05), but not for modified well-known fairy tales. DA at retrieval was associated with a larger and significant increase in RT compared with RT performed alone (all P < 0.0001). In NCs, DA during the encoding of the three types of stories did not affect significantly RT compared with RT performed alone (all P > 0.05), whereas DA during the retrieval of the stories was associated with a significant increase of RT (all P < 0.0001). For the three types of story, both Alzheimer’s disease patients and NCs showed significantly higher RT in the DA at retrieval condition compared with the DA at encoding condition (all P < 0.0001). This result, in line with previous studies, shows that in NCs, DA at encoding has little or no effect on RT, whereas DA at retrieval has a larger and reliable effect on RT. This latter effect is confirmed in Alzheimer’s disease patients, who also show a smaller but significant attentional cost in the DA at encoding condition for unknown stories and well-known fairy tales.

RT at encoding did not vary significantly across stories either in NCs or in Alzheimer’s disease patients (all P > 0.05). RT at retrieval did not vary significantly across stories in NC; whereas in Alzheimer’s disease patients, RT at retrieval were significantly higher for the well-known fairy tales and in the modified well-known fairy tales compared with the unknown stories (both P < 0.05).

**Discussion**

In this study, we described the performance of a group of mild Alzheimer’s disease patients and a group of NCs in the recall of three different types of stories, a previously unknown story, a well-known fairy tale and a modified well-known fairy tale, under three different encoding/retrieval conditions. The aim of the study was to test the hypothesis that in confabulation over-learned information interferes with the recall of specific, unique past episodes and that interference would be more prominent when encoding is perturbed compared with when retrieval is impaired. Accordingly, we predicted that Alzheimer’s disease patients confabulate more in the recall of the modified well-known fairy tales and particularly so when encoding of the to-be-remembered story is perturbed by a concurrent task.

Consistent with our predictions, the main finding of this study demonstrates that division of attention during the encoding phase of a memory task markedly increases the number of confabulations, both in Alzheimer’s disease patients and in elderly NCs, whereas division of attention at retrieval has no effect on confabulation, and that this effect of DA at encoding on confabulation is more prominent when to-be-remembered and over-learned information share common elements. These data provide the most direct evidence to date that the disruption of encoding processes plays a major role in confabulation, whereas the disruption of retrieval processes has no influence on the production of confabulation and also demonstrate that confabulation is more likely to occur when over-learned information interferes with the recall of the to-be-remembered information. The effect of the type of to-be-remembered material and attentional condition on recall was particularly evident when considering total recall and the percentage of confabulation on total recall for each group. In fact, the variation of attentional conditions at encoding and at retrieval had an effect on NC’s but not on Alzheimer’s disease patients’ total recall. Furthermore, the type of story influenced total recall in NC, whereas this effect was less evident in Alzheimer’s disease patients. In contrast, the effect of type of story and of attentional conditions on the percentage of confabulations was more prominent in Alzheimer’s disease patients than in NCs. This shows that in Alzheimer’s disease patients, the attentional manipulation does not affect the quantity of retrieved contents but it does affect its quality. In other words, in Alzheimer’s disease patients, DA at encoding does not reduce the total number of elements recalled but increases the proportion of confabulations on the total number of elements recalled, and this is particularly evident for the recall of the modified
well-known fairy tales. So, compared with NCs, the reduction of attentional processes at encoding and the recall of the modified well-known stories (those in which over-learned information interferes with unique events) affect disproportionately the production of confabulation in Alzheimer’s disease patients.

Overall, compared with Alzheimer’s disease patients, NCs produce few confabulations, but are not completely immune from this type of memory distortion. This confirms that normal memory is vulnerable not only to forgetting but also to memory distortion, and in particular when encoding is impoverished and when over-learned information interferes with the recall of new information.

Many theorists have concluded that confabulation is related to a deficit in retrieval rather than encoding due to the notion that confabulation may affect remote memories acquired long before brain damage occurred as much as recent, anterograde memories that were acquired subsequently (Moscovitch, 1995; Burgess and Shallice, 1996; Conway, 1996; Moscovitch and Melo, 1997; Gilboa and Moscovitch, 2002; Gilboa et al., 2006). However, to date, there are no studies providing direct evidence for the involvement of a retrieval deficit in confabulation.

In addition, it has been shown that confabulation may follow a temporal gradient, affecting recent memories more than remote, pre-morbid memories, which are well encoded and consolidated (Kopelman et al., 1997; Dalla Barba et al., 1998). Our present findings do not support a retrieval account of confabulation, but rather show that poor encoding is directly involved in confabulation. It is possible, however, that confabulations elicited with the experimental paradigm described in this study, are different from the florid and bizarre elaborations that constitute some of confabulation described as ‘spontaneous’ (Kopelman, 1987; Conway and Tacchi, 1996; Schneider et al., 1996b). In spontaneous confabulations, which are often associated with lesions of the ventromedial frontal cortex, a retrieval deficit account remains an open hypothesis. A retrieval deficit together with factors, including among others, motivation (Conway and Tacchi, 1996), reality monitoring (Johnson, 1991), temporal confusion (Schneider et al., 1996b) and temporal consciousness (Dalla Barba et al., 1997) may all play a role in confabulation. The results of this study provide direct evidence that poor encoding also plays a significant role in confabulation. This suggests that rehabilitation strategies geared toward improving encoding may be helpful in contrasting and reducing confabulation. This possibility is indirectly supported by Diamond et al.’s findings (1997), who showed that increasing the amount of information encoded in patients with orbitofrontal lesions yielded a significant improvement in immediate recall.

Since the pioneering work of Bartlett (1932), there is a large consensus on the idea that memory is often a constructive process. Descendents of Bartlett’s theory, called together ‘schema’ theories, propose that what is encoded or stored in memory, is heavily determined by a guiding schema or pre-existing knowledge and information (e.g. Alba and Hasher, 1983; Spaniol and Bayen, 2002; Schacter and Addis, 2007). According to these theories, when subjects cannot remember, they may guess according to prior knowledge, especially when their memory is poor (Spaniol and Bayen, 2002). In the present study, there was no evidence that subjects were guessing when confabulating. The results, however, are not incompatible with schema theories in that they show that schema-driven knowledge or over-learned information affects significantly confabulation. The original contribution of our present results is showing that Alzheimer’s disease patients have a disproportionate deficit in contrasting over-learned information and this deficit is particularly evident when encoding of the to-be-remembered material is impoverished.

Our subjects confabulated more when DA perturbed the encoding of the modified fairy tales. The modified fairy tales are composed of elements in common with the original, over-learned version of the fairy tale (e.g. Little Red Riding Hood went to visit her grandmother), and of elements, which differ considerably from the original version of the fairy tale (Little Red Riding Hood is not eaten by the wolf). Therefore it is likely that the representation of the original version of the fairy tale is activated by elements in common with the modified version. The activation of the representation of the original over-learned version of the fairy tale interferes with the recall of the episodic representation of the elements of the modified version, which differ from the original version. In fact, in the modified well-known fairy tales, confabulations always consisted of elements of the original version of the story. These results provide direct experimental evidence for the idea formalized in Dalla Barba and co-workers’ interpretation of confabulation (Dalla Barba et al., 1997, 1999; Dalla Barba, 2000, 2001, 2002). They argued that confabulation in episodic memory is the result of a condition in which events that are poorly encoded and therefore do not have a strong representation in long-term memory are replaced by more stable representations in long-term memory, with the result that habits or over-learned semantic information are mistaken for specific unique personal episodes. When encoding is defective, like in confabulatory amnesias, or experimentally impoverished by distraction as in this study, the competition between specific to-be-remembered information and over-learned information is biased to the advantage of the latter [see Foerde et al. (2006) for a related view].

It has been proposed that confabulation may reflect a normal reaction to defective learning (Kopelman, 1987). The present results are consistent with this interpretation in that interference of over-learned information with episodic recall might reflect intensive effort to recall poorly encoded material. This explanation is indirectly supported by the significant, negative correlation between the number of confabulations and the number of correct responses. This correlation may in fact reflect the tendency to ‘replace’ poorly encoded material with other information.

Alzheimer’s disease patients are known to make an abnormally high rate of intrusions, a confabulatory like phenomenon (Dalla Barba, 1993b), in word lists recall and intrusions have been considered sufficiently characteristic of Alzheimer’s disease to be helpful diagnostically (Fuld et al., 1982). However, it has been shown that when encoding is reinforced the number of intrusions produced by Alzheimer’s disease patients falls dramatically (Dalla Barba et al., 1995; Dalla Barba and Wong, 1995). Our present results are consistent with these findings in that they demonstrate that when encoding is weakened by the co-occurrence of a secondary task, the probability of observing confabulatory errors during recall increases significantly.
An important finding in this study is that, whereas DA at encoding affects performance for both groups of participants and for both correct responses and confabulations, performance hardly changes at all between FA and DA at retrieval. From the work of Craik and co-workers (Craik et al., 1996; Anderson et al., 1998; Naveh-Benjamin et al., 1998, 2000), we know that DA at encoding has a significant detrimental effect on memory performance but little or no effect on the speed of responding to a secondary task, whereas DA at retrieval has little or no effect on memory performance, but significantly increases RT in the secondary task. The results reported here confirm these previous findings and extend them to confabulations. This pattern of results may be understood in terms of participants putting much more weight on memory retrieval, which thus remains the same as under FA, but at the cost of greatly increased RT, which are doubled and even tripled in the DA at retrieval condition. Although this possibility cannot be excluded, our findings show a somehow paradoxical negative correlation between RT and correct responses in both DA at encoding and DA at retrieval. Conversely, we show a positive correlation between RT and confabulations in the DA at retrieval condition of the well-known stories. This suggests that accuracy of response is not directly dependent on the performance on the RT task.

In conclusion, the present results show the implication of two previously undemonstrated phenomena in the production of confabulation in Alzheimer’s disease: the effect of poor encoding and the interference of strongly represented, over-learned information in episodic memory recall. It is well known that the hippocampus and related structures are crucial for encoding and consolidation of episodic memories. The early involvement of these structures in Alzheimer’s disease may account for the disproportionate sensitivity to interference at encoding. Damage to the hippocampus and related structures, as in early Alzheimer’s disease, may also make these structures particularly vulnerable to interference of inputs from other temporoparietal cortical areas. In this view, confabulation may reflect the interference of knowledge and over-learned information represented in temporoparietal cortex on the activity of structurally and functionally reduced medial temporal lobe structures.

References

Dalla Barba G. Beyond the memory trace paradox and the fallacy of the homunculus: a hypothesis concerning the relation between memory, consciousness and temporality. J Conscious St 2001; 8: 51–78.
De Anna F, Attali E, Freynet L, Foubert L, Laurent A, Dubois B, et al. Intrusions in story recall: when over-learned information interferes with


