In: Focus on Neuropsychology Research
Editor: Joshua R. Dupri, pp. 163-184
ISBN 1-59454-779-3

Chapter 7

NEUROPSYCHOLOGY AND PSEUDO-MEMORIES

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ABSTRACT

Although the power of memory is evident in various daily life experiences (e.g., personal history, knowledge of facts and concepts, and learning of complex skills), memory also has its fallible side. Memory experiences are encoded as separate pieces of a puzzle. At retrieval, this puzzle has to be reconstructed. This reconstruction makes our memory susceptible to distortions. Inspired by ongoing discussions about recovered memories, researchers have studied personality and social factors that make people vulnerable to memory distortions, including pseudo-memories. Recent studies highlight the role of higher cognitive functions in reconstructing our memories. This chapter aims to give an overview of the current state of affairs linking executive functions to pseudo-memories. Evidence from aging, lesion, and imaging studies (Positron Emission Tomography and functional Magnetic Resonance Imaging) will be discussed. Studies conducted in our laboratory also suggest that suboptimal inhibition, monitoring and working memory functions contribute to the development of pseudo-memories. Explaining and identifying the neural basis of pseudo-memories can be regarded as a promising and new domain within neuropsychology.

INTRODUCTION

Throughout history, memory has been described in terms of different metaphors: from a wax tablet (Plato) up to the popular computer metaphor in our times (Draaisma, 2000; Merckelbach and Wessel, 1998). Although the power of memory is evident in daily life,

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memory is imperfect (e.g., Kopelman, 2002; Schacter, 1999). Events and experiences may be remembered in a distorted way. Thus, for example, an eyewitness may remember a yellow taxi, when actually the taxi's colour was blue. This is what has been termed a distortion (Gudjonsson and Clare, 1995). Sometimes events are completely fabricated, as was the case with BH (see below). But even neuropsychologically intact people may make such commission errors. An example is the eyewitness who remembers a blue taxi, when in fact there was no taxi at all. Throughout this chapter, we will refer to this type of error as pseudo-memory although we are aware of the fact that the term "false memory" is more common. Regardless of terminology, an important point about distortions and commissions is that they make plain that the idea of memory as a reproductive entity, in which events are reproduced with photographical precision, does not hold. Instead, memory is reconstructive, precisely because events are encoded in an incomplete and fragmentized way. When retrieving an experience, different fragments have to be combined to form an entity. Almost 40 years ago, Neisser used the analogy of the palaeontologist when describing memory. He wrote: "Out of the few stored bone chips we remember a dinosaur" (Neisser, 1967, p. 285).

Over the last two decades, the reconstructive nature of memory has informed scientific and popular discussions about, for example, recovered memories of childhood sexual abuse (e.g., Loftus and Ketchman, 1994; Schacter, 2001). Until recently, neuropsychological research in this domain was limited to case studies of neurological patients with peculiar memory illusions (e.g., Parkin, Bindschaedler, Harsent, and Metzler, 1996). In recent years, inspired by ongoing debates about the "accuracy" of human memory and its legal implications (Koriat, Goldsmith, and Pansky, 2000; Loftus, 2003), there has been an increased interest in neurocognitive research on pseudo-memories. The introduction of modern imaging techniques such as functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET) has also stimulated new studies in this field (e.g., Kopelman, 1999; 2002; Schacter and Slotnick, 2004). One important antecedent of pseudo-memories is a breakdown in what has been termed, *source monitoring* (Johnson, Hashtroudi and Lindsay, 1993). Source monitoring is a mechanism that serves as a screening and controlling device for memory at retrieval. It refers to cognitive processes involved in determining the source of memory information. Recent neurocognitive findings localize this function in a network encompassing the prefrontal cortex. In this chapter, we will give an overview of past, present, and future developments in neuropsychological research on pseudo-memories. A recurring theme in our review of the literature is the importance of frontal lobes for memory. The reconstructive nature of memory becomes most compelling in case studies on patients with frontal lobe damage (e.g., Parkin et al., 1996; Schacter, Curran, Gallucio, Milberg, and Bates, 1996a; Delbecq-Derousne, Beauvois, and Shallice, 1990). The patients in these case studies had a tendency to falsely recognize non-presented stimuli as being previously presented (e.g., Parkin et al., 1996), misattributed the source of their memories (e.g., Janowsky, Shimamura, and Squire, 1989), or recollected fictitious events (e.g., Dalla Barba, 1993). Following the tradition of these case studies, we will briefly describe patient BH, who underwent a neuropsychological evaluation at our memory lab. We will use this case as the starting point for a more systematic analysis of the neuropsychology of pseudo-memories.

CASE BH

On February 19th 1985, at 3 a.m., two policemen find a confused man in the red light district of Amsterdam. He is unable to respond to questions and comments. The man makes an anxious impression, is disoriented in time, place, and person and finds himself in a state of mutism. A head injury is suspected. The police believe that he might have been involved in a fight. At the hospital, a CT scan is made, but no neuroanatomical abnormalities are detected. From March 1st until June 20th 1985, BH stays in a psychiatric hospital. He still does not talk and communicates with other patients and clinicians by writing in French. Neurological examination shows no abnormalities, but his performance on several neuropsychological tests does suggest residual signs of brain damage. His main complaint is that he cannot remember anything before February 19th 1985. Nonetheless, BH is dismissed from hospital with a diagnosis of neurotic amnesia. Since that time, BH occasionally received psychotherapeutic treatments (among which hypnotherapy), but his memory complaints did not disappear.

During spring of 2002, we saw BH, who still had no autobiographical memory for events that took place prior to February 19th 1985. We administered a neuropsychological test battery and collected psychophysiological data. We found his most recent Full Scale IQ to be 110. His score on a long term verbal memory task (Auditory Verbal Learning Test; AVLT; Deelman, Brouwer, van Zomeren, and Saan, 1980) was excellent, but he performed poorly on a working memory task (i.e., digit span subtask of the Wechsler Adult Intelligence Scale; For a Dutch translation, see Stinissen, Willems, Coetsier, and Hulsman, 1970). His performance on the Trail Making Task (Reitan, 1958; Reitan and Wolfson, 1993), which is sensitive to frontal (i.e., executive) dysfunctions, was also very poor. He scored low on memory for famous events up until 1985 (e.g., Mayes, Downes, McDonald, Rooke, Sagar, and Meudell, 1994; Sanders and Warrington, 1971). However, his memory for news facts from 1985 through 2002 was intact. His score on the SIMS (Structured Inventory of Malingered Symptomatology; Merckelbach and Smith, 2003) was above the cut off, indicating the tendency to endorse bizarre and rare symptoms. Patient BH did not show any autonomic responsivity (heart rate, skin conductance) during trials on which relevant information pertaining to his past or present state (e.g., the name of his mother) was presented. During an interview, three further features became apparent: A paresis on the left side of his body, an indifferent attitude, and a tendency to react with confabulatory responses. That is, when presented with fictitious names, BH produced bizarre confabulations that included these names.

As said, CT scans performed during the mid eighties did not reveal any abnormalities in the brain of BH. It should be noted though that a normal CT scan does not rule out the presence of prefrontal brain dysfunction. There are several examples in the literature where patients with normal CT scans had brain dysfunction that became only apparent when other neuroimaging techniques were used (e.g., Kopelman, Green, Guinan, Lewis, and Stanhope, 1994; Reed, Marsden, Lasserson, et al., 1999). Our patient's working memory impairments, his deficits in executive functions, and his tendency to confabulate clearly indicate right prefrontal cortex damage (see also Kopelman, 1999; Weinstein, 1996). BH's left sided paresis further supports this interpretation. His autonomic hyporesponsivity is consistent with damage to the right dorsolateral prefrontal cortex (Caltagirone, Zoccolotti, Originale, Daniele, and Mammucari, 1989; Tranel and Damasio, 1994; Zoccolotti, Scabini, and Violani, 1982).

The case of BH demonstrates the importance of the prefrontal cortex for accurate recall of past events. Damage to this region of the brain may lead to confabulations – one particular type of pseudo-memories. What more can neuropsychology tell us about the creation of pseudo-memories? It is to this issue that we now turn.

PAST: FROM REPRODUCTION TO RECONSTRUCTION

In line with the revival of Sir Frederic Bartlett's work (1932), cognitive psychologists have developed various experimental paradigms to elicit memory errors, some of which involve pseudo-memories (e.g., Loftus, Miller and Burns, 1978). During the nineties, research on memory errors was inspired by the debate about the accuracy of traumatic memories recovered during psychotherapy (Loftus, 1993; Loftus and Ketchman, 1994; Read and Lindsay, 1997).

Commonly used techniques in pseudo-memory research comprise the post-hoc misinformation paradigm (Ceci and Bruck, 1993; Loftus and Palmer, 1974), the imagination-inflation paradigm (Garry, Manning, Loftus, and Sherman, 1996; Horselenberg, Merckelbach, Muris, Rassin, Sijsenaar, and Spaan, 2000), and semantic relatedness paradigms (Deese, 1959; Peters, Jelicic, Haas, and Merckelbach, *accepted*; Roediger and McDermott, 1995). We will briefly discuss each technique.

Exposure to (post-hoc) misinformation can have detrimental effects on the accurate recollection of a specific event (for a review, see Loftus, Feldman and Dashiell, 1995). An example may clarify this: Suppose that person X is a witness to an accident, caused by a car that did not stop at a stop sign. During the interrogation of person X, a police officer asks person X what happened when the car did not stop at the yield sign. Research by, for example, Loftus and Palmer (1974) and Loftus and colleagues (1978), shows that there is a high probability that person X will recall the car did not stop at the yield sign. Thus, subtle suggestions provided after the event has occurred (i.e., post-hoc) may distort the way in which people come to remember the event (see also Crombag, Wagenaar, and van Koppen, 1996; Ost, Vrij, Costall, and Bull, 2002).

Encouraging people to fantasize about events that they have never experienced is the crux of the imagination-inflation paradigm. Imagining about an improbable event can lead to an increase in subjective confidence that the event did take place (Garry et al., 1996). Consider the following example: A young man is asked to imagine how he, at age 5, was a passenger in a hot air balloon. According to the man's parents, such an event never took place. After several weeks, he is asked to assign a confidence rating to the following item: "At age 5, I flew as a passenger in a hot air balloon". It is likely that he will overestimate the probability of the balloon trip compared to items that were not imagined (see also Horselenberg et al., 2000).

In semantic relatedness paradigms (Deese, 1959; Roediger and McDermott, 1995), participants are exposed to cues referring to a critical item that is never presented. For example, in the Deese/Roediger-McDermott (DRM) paradigm, initially developed by Deese (1959) and later modified by Roediger and McDermott (1995), people are asked to remember related words, such as *bed, nap, pillow,* and *snooze,* all of which are associated to a common word, in this particular example, the word *sleep.* The word *sleep,* however, is never presented in the study list and serves as a *critical lure* at test. Following each list presentation, participants are asked to recall the studied words. Once all lists have been presented and recalled, participants are given a recognition test comprising the studied words, unrelated lures, and critical lures. Roediger and McDermott (1995) reported that on average, participants falsely recognized 65-80 per cent of the non-presented critical lure words. These findings were replicated in a follow-up study by Stadler, Roediger, and McDermott (1999).

What post-hoc misinformation, imagination-inflation, and semantic-relatedness techniques have in common is that they produce source monitoring problems (e.g., Johnson et al., 1993). That is, as a result of these techniques, participants find it difficult to differentiate between details that they really perceived and details that they only fantasized about. Obviously, the tendency to accept internally generated experiences as events that really took place is an important step in the direction of a full-blown pseudo-memory (see also, Smeets, Merckelbach, Horselenberg, and Jelicic, 2005). Clearly, some people are more susceptible to such source monitoring problems than are others. A case in point are schizophrenic patients whose core symptoms (e.g., hallucinations) reflect serious source monitoring difficulties (e.g., Keefe, Arnold, Bayen, and Harvey, 1999; Moritz, Woodward, and Ruff, 2003). In line with this, recent studies explored whether more subtle personality traits may be related to source monitoring problems elicited by imagination-inflation techniques and so on. Thus, traits like dissociation, suggestibility, and imagery vividness have been studied to find out whether they modulate performance on these laboratory tasks (e.g., Eisen and Lynn, 2001). While research along these lines has yielded important clinical insights, its theoretical contribution is limited. This has to do with poor explanatory power of personality traits. Focussing on neuropsychological concepts may explain why certain traits are related to pseudo-memories and, therefore, this research line might be more fruitful. Indeed, recent aging and lesion studies suggest that executive functions such as monitoring and inhibition play a critical role in the creation of pseudo-memories. It is to this research domain that we now turn.

PRESENT: THE NEUROPSYCHOLOGY OF MEMORY AND PSEUDO-MEMORY

A scholarly review on the neuropsychology of memory can be found in Greenberg and Rubin (2003) and Squire and Schacter (2002). Briefly, these authors argue that when attention is paid to stimuli, different regions of the primary sensory and association cortex are activated (Thus, a visual stimulus activates the visual cortex, whereas auditory stimulation activates the auditory cortex). The role of the medial temporal lobe can best be regarded as a switchboard, linking up different brain regions that are simultaneously activated during the encoding of a specific event. When one wants to recollect/retrieve this specific event, certain structures in the medial temporal lobe mobilize different regions in the sensory and association cortex.

The prefrontal cortex is involved in search strategies and the evaluation of their results. Its primary role is evaluating and monitoring relevant information and inhibiting irrelevant information (retrieval). That is, the prefrontal cortex organizes, selects, and activates the correct representation from the various representations that are encoded and consolidated at different points in time (Nyberg, Cabeza, and Tulving, 1996). More specifically, the left prefrontal cortex sustains organizing the encoded information in the most efficient way for later remembering (Fletcher, Shallice, Frith, Frackowiak, and Dolan, 1998). In contrast, the right prefrontal cortex guides retrieval (Kapur, Craik, Jones, Brown, Houle, and Tulving, 1995; Wheeler, Stuss, and Tulving, 1997) and some authors (e.g., Markowitsch, 1996) believe that it is particularly involved in the retrieval of autobiographical memory.

In his review article on the neuropsychology of pseudo-memories, Parkin (1997) states that prefrontal damage may lead to different memory distortions. Patients with prefrontal damage show a decreased usage of strategic retrieval and control (e.g., monitoring, evaluation, inhibition). This often leads to an endorsement of irrelevant memory representations during the retrieval of a specific event (Shimamura, 1995). Evidence for this can be found in case studies involving patients with focal brain damage, aging research, research using functional imaging techniques, and individual difference studies.

Brain Damage and Aging

As mentioned before, initial evidence for the role of the prefrontal cortex in the creation of pseudo-memories came from several case studies (e.g., Delbecq-Derousne et al., 1990; Parkin et al., 1996; Schacter et al., 1996a). The patients described in these papers had the initials JB (Parkin, Leng, Stanhope, and Smith, 1988; Parkin et al., 1996), BG (Curran, Schacter, Norman, and Gallucio, 1997; Schacter et al., 1996a), and RW (Delbecq-Derousne et al., 1990; see also patient MR; Ward, Parkin, Powell, Squires, Townshend, and Bradley, 1999; patient JT; Young, Flude, Hay, and Ellis, 1993; Patients WJ and BH; Rapcsak, Polster, Comer, and Rubens, 1994). Patients JB and RW were both diagnosed with a ruptured aneurysm of the anterior communicating artery (ACoA), whereas patient BG was diagnosed with an infarction located in the right frontal lobe. These three patients exhibited an extremely high rate of false recognition errors in a forced-choice recognition task (indicating new unrelated words and/or critical lures as old). The data of JB further revealed a recall impairment in which intrusion rates (i.e., producing non-presented words) were abnormally high. Ward and colleagues (1999) described a patient (MR) who was able to correctly recognise famous people, but also had a strong tendency to falsely classify unfamiliar people as familiar (see also Rapcsak, Reminger, Glisky, Kaszniak, and Comer, 1999). This patient had had a lacunar infarction in the area above the left lateral ventricle adjacent to the left frontal horn.

Recent attempts to explore the separate contributions of medial temporal and prefrontal areas to memory have supported the findings from these case studies. A study by Melo, Winocur, and Moscovitch (1999) examined patients with isolated damage to the medial temporal or the prefrontal areas. The results showed that patients with medial temporal lesions made significantly less false recognition errors in comparison to those with prefrontal lesions.

Relative to younger adults, neurologically intact elderly tend to make more false recognition errors. Using the DRM paradigm, a recent study by Butler, McDaniel, Dornburg, Roediger, and Price (2004) investigated the relationship between neuropsychological measures of frontal lobe functioning and age differences in false recall. These authors found that older adults were less successful in reproducing studied items and more often falsely recalled the non-presented, critical lure words in comparison to younger adults, which is in line with other studies (Balota, Cortese, Duchek, Adams, et al., 1999; Cohen and Faulkner, 1989; Dywan and Jacoby, 1990; Intons-Peterson, Rocchi, West, McLellan, and Hackney, 1999; Koutstaal and Schacter, 1997; Norman and Schacter, 1997; See review by Schacter, Koutstaal, and Norman, 1997). These pseudo-memories were not related to the length or elaboration of the learning phase (Kensinger and Schacter, 1999). Most importantly, Butler and colleagues (2004) showed that these pseudo-memories were intimately linked to measures of frontal lobe functioning (i.e., executive functions). That is, only older adults characterized by poor frontal lobe functioning exhibited heightened levels of false recollections. Older adults with intact frontal lobe functioning and young adults had similar levels of accurate and false recall. In line with this, imaging studies of older adults show deviant activation patterns in the prefrontal cortex during memory tasks. This is most prominent when they have to rely on controlled retrieval strategies during these tasks (Schacter, Savage, Alpert, Rauch, and Albert, 1996b).

There are also indications that older adults are more suggestible compared to younger people. Evidence for this comes from studies using the post-hoc misinformation paradigm (e.g., Multhaup, De Leonardis, and Johnson, 1999). As stated earlier, the crux of this paradigm is that participants are exposed to an event and then later receive misleading information about this event. When older adults are asked to reproduce the original event, they typically tend to include the misinformation at higher rates relative to control conditions (see also Mitchell, Johnson, and Mather, 2002).

Recent studies have begun to explore pseudo-memories in individuals who suffer from Dementia of the Alzheimer Type (DAT; see Balota et al., 1999; Budson, Sullivan, Daffner, and Schacter, 2003; Marsch, Balota, and Roediger, 2005, Waldie and Kwong See, 2003; Watson, Baltoa, and Sergent-Marshall, 2001). Basically, these studies show that DAT patients are especially susceptible to pseudo-memories when pre-existing semantic information is activated. In a study with a mixed sample including various age groups and various levels of cognitive impairment (young, healthy old adults < 80 years, healthy old adults > 80 years, very mild DAT, and mild DAT), Watson and colleagues (2001) exposed their participants to a series of semantic memory tasks, including the DRM paradigm. Their results indicated that accurate recall decreased with increasing age and dementia severity. However, false recall of the non-presented critical lure words increased with age and remained fairly stable across dementia severity. In a later study by Waldie and Kwong See (2003), these findings were replicated using the DRM paradigm. These authors also gave an old-new recognition task to their participants. The recognition task comprised old (studied) words, non-presented critical lure words, and non-presented related and unrelated distracter words. The DAT group and healthy elderly showed similar rates of false recognition of non-presented critical lure words. However, in comparison to healthy elderly, patients with DAT were more likely to classify non-presented related and unrelated distracter words as old (presented) words.

An explanation for these findings is offered by an inefficient functioning of cognitive inhibitory control that occurs with aging and DAT, and is related to prefrontal (executive) dysfunction. Inhibitory control is important in limiting the spread of activation during retrieval of semantic material. Decreased inhibitory control results in increased spreading activation in the semantic network and, as a consequence, increased probability that one falsely remembers a non-presented critical lure word. Clearly, cognitive inhibition is a function of the prefrontal cortex.

Functional Imaging Data

Which functional brain areas are involved in accurate memories and pseudo-memories? To address this issue, researchers have used various neuroimaging techniques. A complete description of the different fMRI, PET, and electroencephalogram (EEG) studies is beyond the scope of this chapter (see Schacter and Slotnick, 2004, for a thorough overview of research in this area). In a prototypical PET study, Schacter, Reiman, Curran, Yun, et al. (1996c) focussed on true and false recognition in the DRM task. The authors found two trends. To begin with, an increased activation in left temporal region was found during accurate recall of presented words. Second, there appeared to be an increase in right prefrontal activity during false recognition of critical lures. Using fMRI during a follow up study, the same researchers noted a similar pattern (Schacter, Buckner, Koutstaal, Dale, and Rosen, 1997). In this study, a delayed onset of prefrontal activation during false recognition occurred, a phenomenon that the authors relate to suboptimal controlling of the prefrontal cortex during retrieval. A number of other studies have tried to disentangle the brain mechanisms involved in accurate and pseudo-memories (for reviews, see Dodson and Schacter, 2002; Gonsalves and Paller, 2002; Schacter and Slotnick, 2004). By and large, neuroimaging research demonstrates that, in addition to a (modest) involvement of the medial temporal cortex, the prefrontal cortex plays a leading role in errors that may occur during retrieval and, therefore, in pseudo-memories more specifically.

According to Dodson and Schacter (2002), delayed prefrontal activity during false recollection found in neuroimaging experiments would reflect a failure in executive functions, more specifically inhibitory functions that operate during retrieval. Inhibition can be defined in terms of accurate discrimination between target information and similar competing information in memory at retrieval (e.g., Anderson and Spellman, 1995). Accordingly, a lack of inhibitory function would lead to a less reliable retrieval, and as a consequence source monitoring difficulties.

Individual Differences

Another research line has focused on individual differences in susceptibility to pseudo-memories. As mentioned before, personality traits like dissociation, suggestibility, and imagery vividness have been studied to examine whether they predict performance on tasks that elicit pseudo-memories (e.g., Candel, Merckelbach, and Kuijpers, 2003; Horselenberg et al., 2000; Winograd, Peluso, and Glover, 1998). This research approach has found strong evidence that high scores on, for example, dissociation are linked to heightened levels of false recall (e.g., Candel et al., 2003; Geraerts, Smeets, Jelicic, van Heerden, and Merckelbach, 2005). But what does this mean? Is dissociation a causal antecedent of pseudo-memories? Or is it just a manifestation of heightened susceptibility to pseudo-memories? This causal issue is extremely difficult to examine. Linking individual differences in inhibition and other executive functions to pseudo-memories is perhaps a more promising way. A fine example of this is an individual difference study by Alexander, Goodman, Schaaf, Edelstein, et al. (2002). These authors interviewed children (n = 51) between the ages of 3 and 7 years about an inoculation that they had undergone two weeks earlier. Children's memory accuracy and suggestibility were examined in relation to their stress levels during inoculation, parental attachment styles, and cognitive inhibition (i.e., suppression of irrelevant information). The authors anticipated that children with higher levels of cognitive inhibition would provide more accurate information and would be less suggestible than children with lower levels of inhibition. This was borne out by the data. That is, children with poorer cognitive inhibition exhibited more pseudo-memories on a free recall task about inoculation and more often accepted misleading information than children with adequate inhibition capacity. This difference remained, even when controlling for age. More recently, Lödvén (2003) investigated the underlying mechanisms of age effects on pseudo-memories. A total of 146 participants, aged 20 to 80 years were subjected to tasks measuring processing speed, inhibition, episodic memory performance, and pseudo-memories. Results revealed an increased level of pseudo-memories with increasing age. Using structural equation modelling, this author found that impairments in inhibitory control affected susceptibility to pseudo-memories indirectly via episodic memory performance. That is, participants scoring low on episodic memory tasks made more false recall critical lure intrusions, compared to participants scoring high on these episodic memory tasks. In explaining inhibitory control, participants with an impaired inhibition function showed limited episodic memory performance. Inhibitory control influenced pseudo-memories only indirectly, via an influence on episodic memory.

Empirical Intermezzo

Although the neuropsychology of pseudo-memories has mostly been studied in neurological patients (Melo et al., 1999), older people (Lödvén, 2003), and children (Alexander et al., 2002), it is not unreasonable to assume that even in healthy samples, there is individual variation in the efficacy of executive functions. This variation, in turn, might be the origin of individual differences in susceptibility to pseudo-memories. To address this issue, we explored whether executive function in undergraduate students is linked to false recall and recognition as measured with the DRM paradigm (Peters et al., *accepted*). Because monitoring of memory retrieval does involve inhibition of competing schemata, we expected that individual differences in the ability to inhibit cognitive schemata were related to false recollections in the DRM paradigm. The Random Number Generation (RNG) task was used to assess individual differences in the ability to inhibit cognitive schemata (as measured by the seriation subscale of the RNG task; Ginsburg and Karpiuk, 1994; Williams, Moss, Bradshaw, and Rinehart, 2002). In this task, participants have to generate digits in a random sequence. Participants are asked to produce long sequences of the numbers 1-10 in a random fashion. Successful performance on the RNG requires efficient control of response generation and suppression, as people have to suppress (i.e., inhibit) their natural preference for counting in series. The RNG has been effective in detecting loss of cognitive flexibility in a number of neurological diseases like, for example Parkinson's disease (Brown, Soliveri, and Jahanshahi, 1998) and autism (Williams et al., 2002). Several RNG parameters have been proposed to measure the various departures from randomness and, thus, lack of inhibitory control (Ginsburg and Karpiuk, 1995). A factor analysis on RNG data revealed three types of parameters. The first type involves repetition, which is related to output inhibition. The second is cycling and relates to successful monitoring of previous output, while the third and most important type is seriation, which contains inhibition of cognitive schemata (Williams et al., 2002). High seriation scores indicate a lack of inhibition of cognitive schemata (i.e., less efficient executive functioning), with low seriation indicating efficient executive functioning (i.e., one can inhibit the cognitive schema of counting in series).

Seventy-two undergraduate students took part in our study. They were subjected to both the DRM and the RNG. The DRM paradigm (Deese, 1959; Roediger and McDermott, 1995) involves 16 selected lists, each consisting of 15 words semantically related to a non-presented critical lure. After each list presentation, participants were given 2 min to write down all the words they could remember. After the final recall test, participants were given an old-new recognition task consisting of 16 critical lures of the studied lists completely intermixed with 48 study words (the 1st, 8th and 10th word of each studied list) and 32 unrelated lures. Mean DRM recall and recognition scores together with RNG task scores can be found in table 1. We found a significant link between recognition of critical lures of the DRM paradigm and the seriation scores (r = 0.36) of the RNG. Similarly, there was a borderline significant correlation between recall of critical lures and seriation (r = 0.23). When extreme groups were formed on the basis of participants' RNG seriation subscale performance (i.e., performance below the 25th or above the 75th percentile), no differences between these groups emerged in terms of accurate recall or recognition. However, those scoring high on seriation (reflecting a lack of inhibition of cognitive schemata) also had high false recognition rates of critical lures compared to those scoring low on seriation, mean proportion recognition rates being 0.63 (SD = 0.24) and 0.37 (SD = 0.30), respectively. Likewise, participants scoring high on seriation had higher false recall rates of critical lures relative to those scoring low on seriation, means being 0.28 (SD = 0.17) and 0.19 (SD = 0.16), respectively (see figure1).

Table 1. Mean proportion scores of an undergraduate sample (*n* = 72) on DRM recall and recognition of studied words and critical lure words, and overall mean scores on seriation subscale of Random Number Generation (RNG)

DRM		***Mean (proportion)***	***SD (proportion)***	***Range (proportion)***
	Subtests			
	Recall studied words	0.64	0.07	0.48-0.77
	Recognition studied words	0.83	0.10	0.40-1.00
	Recall critical lure	0.26	0.18	0.00-0.75
	Recognition critical lure	0.49	0.27	0.00-0.94
RNG		***Mean***	***SD***	***Range***
	Subtest			
	Seriation	33.67	7.12	16-54

This pattern of findings demonstrates that even in a healthy sample of undergraduate students, individual differences in executive functions are related to false recollections. Note again that in the high seriation group heightened levels of false recall and false recognition were not accompanied by an increased accurate recall or recognition. Thus, the link between poor executive function and pseudo-memories cannot be explained in terms of better or poorer encoding.

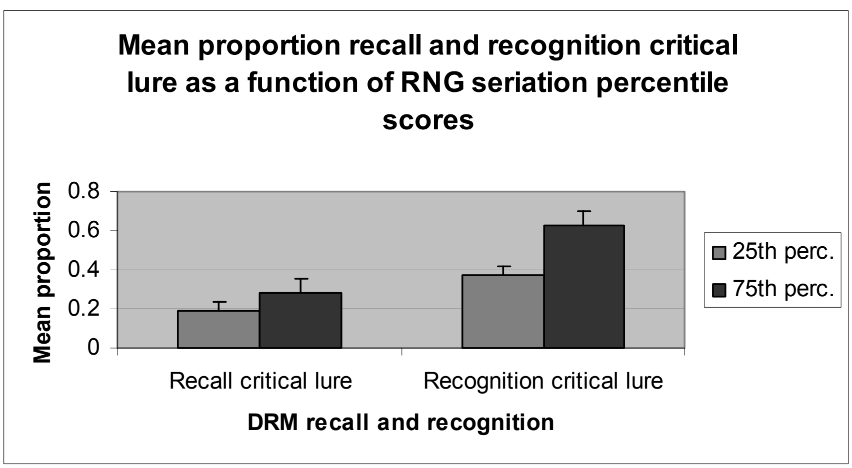

Figure 1. Mean proportion scores of the free recall and recognition of the critical items based on the 25th and 75th seriation percentile scores of the participants (*n* = 72). Error bars indicate SE of mean. A significant differences was found between the 25th percentile and 75th percentile mean proportion scores of the recognition critical lure [$t(36) = 3.15$, $p < 0.01$].

Working Memory

Working memory is closely related to the executive functions of the frontal lobe. A recent paper by Reinitz and Hannigan (2004) describes three experiments relating pseudo-memories to working memory capacity. The authors had their participants (n = 48) study pairs of compound words, either simultaneously or sequentially. The subsequent recognition test included within-pair and between-pair conjunction foils and true conjunction pairs. Overall, the results indicated that intact working memory is necessary for binding stimulus parts together in episodic memory. Inefficient working memory will lead to binding failures, and subsequent an increase in pseudo-memories.

McCabe and Smith (2002) examined age differences in the ability to suppress pseudo-memories, using the DRM paradigm. In two separate experiments, some younger and older adults were unwarned about the potential pseudo-memories occurring as a result of exposure to the DRM procedure. Others were warned before studying the DRM lists. Still others were warned after studying and before testing. Lists were presented at different rates (4 sec/word or 2 sec/word). Individual difference measures like working memory were also administered. Young adults were better in discriminating between studied words and critical lure words when warned about the DRM effect (either before or after study). Older adults were able to discriminate between studied items and critical lure words when given warnings before study, but not when given warnings after study and before retrieval. As to the individual differences measures, working memory capacity predicted false recognition following study and retrieval warning. That is, reduced working memory capacity was associated with higher rates of false recollections. McCabe and Smith (2002) conclude that discriminating between similar sources of activation critically depends on working memory capacity, which declines with advancing age. This leads to a heightened susceptibility to pseudo-memories.

Inspired by these studies on working memory, we conducted an experiment to examine whether individual differences in working memory capacity in a healthy student sample affect the development of pseudo-memories as measured by the DRM paradigm (Peters, Jelicic, Verbeek, and Merckelbach, *submitted*). As a measure of working memory capacity we used digit span (forward and backward) which is a subtask of the Wechsler Adult Intelligence Scale (for a Dutch translation, see Stinissen et al., 1970). Recent work shows that this task activates the right dorsolateral prefrontal cortex (DLPFC), the parietal lobes as well as the anterior cingulate (Gerton, Brown, Meyer-Lindenberg, Kohn, et al., 2004). A total sample of 60 undergraduate students took part in our experiment. Participants were subjected to a Dutch version of the Deese/ Roediger-McDermott (DRM) paradigm (Deese, 1959; Roediger and McDermott, 1995). Participants were given the digit span task after the recall of the 10th DRM list (and before the recognition part of the DRM paradigm). Series of digits were read aloud (e.g. 2 4 7), each series increasing in length (from 2 digits to 8 digits). After each series, participants were asked to repeat this series orally. The test consisted of 12 series in the normal front to back order (forward) and 12 series in the back to front order (backward). The number of correctly reproduced series was used as a measure of working memory capacity.

The overall probability for recalling or recognizing the critical lure was 0.47 and 0.87 (see table 2). No significant correlations were found between either recall or recognition of the study words and the digit span task scores (all p's > 0.05; two-tailed). Mean proportion of recognition of critical lures was significantly correlated with digit span backward scores (r = -0.40; p < 0.01). Similarly, there was a borderline significant correlation between recall of critical lures and digit span backward (*r* = -0.23; *p* = 0.08; two-tailed). Participants who performed poorly on digit span backward more often falsely recognized the critical lure word compared to those who scored high on the backward digit span.

Table 2. Mean proportion scores (including *SD* and Range) of recall and recognition of studied and critical lure words in an undergraduate sample (*n* = 60). Digit Span forward and backward scores are described in overall mean scores

Item type	***Mean***	***SD***	***Range***
Recall studied words	0.61	0.07	0.39
Recall critical lures	0.47	0.19	0.80
Recognition studied words	0.79	0.11	0.47
Recognition critical lures	0.84	0.15	0.60
Digit Span Forward	6.10	1.21	4.00
Digit Span Backward	4.65	1.05	5.00

Multiple linear regression analysis was conducted with the mean proportions of recall and recognition as dependent variables and digit span forward and backward entered as independent variables. The results are shown in table 3. The digit span forward and backward test did not have a significant influence on the recall and the recognition of old (e.g., presented) words (all *p*'s > 0.30). A significant relationship was found between the digit span backwards and the mean proportion recognition of the critical lure words.

Table 3 Summary of Multiple Regression Analysis for variables predicting proportion recall and recognition of critical lure words (*n* = 60)

Variable	***B***	**SE *B***	**Β**	**T**
Recall				
Digit Span forward	3.27	0.02	0.00	0.002
Digit Span backward	-0.04	0.02	-0.23	-1.70*
Recognition				
Digit Span forward	-0.008	0.02	-0.06	-0.51
Digit Span backward	-0.06	0.02	-0.39	-3.10**

Note. R^2 = 0.05 for Recall; R^2 = 0.16 for Recognition digit span backward
* borderline significant *p* = 0.09
** $p < 0.01$

The studies described above converge on the notion that individual differences in cognitive inhibition and working memory are related to pseudo-memories. A lack of cognitive inhibition and/or reduced working memory capacity will lead to a liberal criterion setting and a weakened suppression of irrelevant information. As a consequence, source monitoring errors occur, which may ultimately produce pseudo-memories (see figure 2).

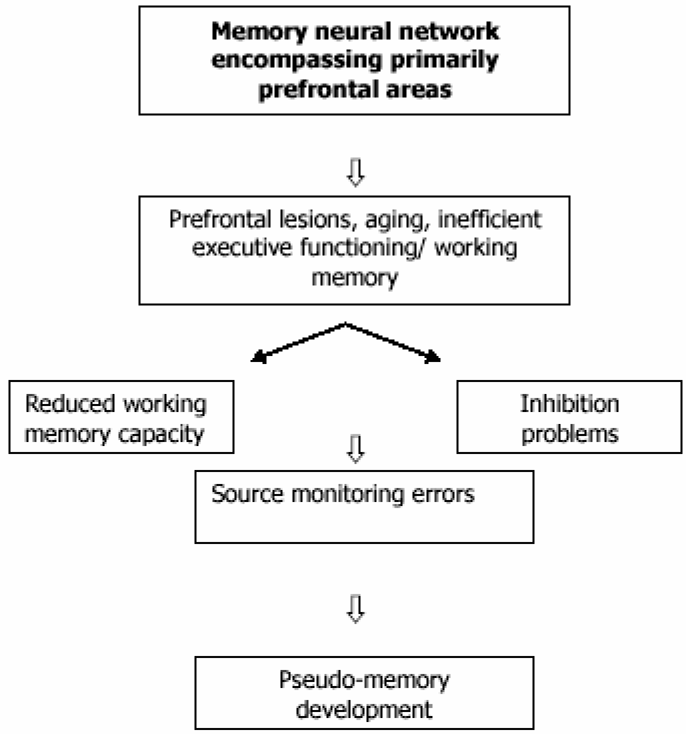

Figure 2. Model on the involvement of prefrontal areas on pseudo-memory development.

FUTURE

A good starting point for further neuropsychological research on the origins of pseudo-memories is the Constructive Memory Framework (CMF) proposed by Schacter and colleagues (Dodson and Schacter, 2002; Schacter, Norman, and Koutstaal, 1998). According to their framework, new experiences are organized in patterns of features that represent different aspects of the experience. For example: The things I did on my birthday, the things I eat on that day, and the various presents I got. These features are encoded across different regions of the brain. The retrieval of this information requires an act of pattern completion, whereby the features belonging to a past experience are activated and the activation spreads along other features (spreading activation). It further proposes that false recollections are modulated by neuropsychological factors operating primarily at encoding or retrieval stages of memory. More specifically, the prefrontal cortex is involved in the updating, suppression, and monitoring of information. There are two problems that have to be solved in order for people to be able to reconstruct accurate memories of past events. First, during the encoding process, features must be connected together to form a "coherent" representation (i.e., the feature binding process). It is also necessary to keep the bound representations separate from each other (pattern separation). Inadequate bindings between features can lead to source memory errors, whereby persons can retrieve specific fragments of an experience, but cannot recall the context of encoding. When, during pattern separation, different experiences overlap, people can sometimes only recall the gist of these experiences. For example, celebrating your birthday is a yearly recurring event. For this reason, connecting the different experiences of this event is preferable. However, the features of your last birthday need to be different from the representations of your previous birthdays. Otherwise you will not be able to distinguish between the different birthday representations.

During retrieval, the memory system must also solve binding and separation problems in order to reconstruct relatively accurate memories of past events. Once memory representations have been retrieved, the memory system faces another problem, referred to by Johnson and colleagues (1993) as the source monitoring problem. This phase of retrieval involves criterion-setting, which determines whether the memory representation is a veridical recollection of an experienced event or a fantasy. In the case of our birthday example this means that during retrieval, sufficient retrieval cues need to be present to remember an accurate representation of this day. Also specific criteria need to be employed to be certain that the retrieved event is the correct experience rather than the product of a dream or fantasy. Lax criterion setting can lead to remembering an experience that we only imagined to have happened.

Neural substrates implicated by this theory involve the medial temporal lobes that sustain encoding and retrieval of recent experiences and the prefrontal cortex that sustain control and the retrieval of old experiences. The CMF emphasizes that the prefrontal cortex sustains both retrieval focus and criterion-setting. Plainly, both require cognitive inhibition of schema-related material. In our studies (Peters, et al., *accepted*; Peters, et al., *submitted*), this aspect was tapped by a reduced ability to suppress stereotypical series of digits (e.g., 2, 3, 4) or reduced working memory capacity. Eventually, a lack of cognitive inhibition may lead to liberal criterion setting and an inability to suppress related information, with the potential consequence of source monitoring deficits.

Conclusion

We believe that the CMF and especially the role of the prefrontal areas in the origins of pseudo-memories warrant further study. It would not only be worthwhile to examine pseudo-memories in special samples, for example patients with brain damage, but also to address pseudo-memories and their correlates in normal, healthy samples. As said before, in healthy samples, there are a number of traits, notably dissociation and depression (or negative affectivity), that seem to predispose to pseudo-memories (e.g., Candel et al., 2003; Horselenberg, Merckelbach, van Breukelen, and Wessel, 2004). On the other hand, the connection between these traits and pseudo-memories is far from robust. That is, some studies were unable to find a significant correlation between for example dissociation and pseudo-memories (Horselenberg et al., 2000). Perhaps, then, traits like dissociation and depression serve as antecedents of pseudo-memories to the extent that they are accompanied by subtle disturbances in executive functions of the prefrontal areas. Thus, the precise connection between dissociation, depression, and executive functions requires systematic study. Note that there is some tentative evidence that dissociative symptoms go hand in hand with mild executive dysfunctions. For example, relying on a sample of forensic patients, Cima and colleagues (2001) found that high levels of dissociative symptoms were related to poor performance on a 'frontal'task (the Behavioural Assessment of Dysexecutive Syndrome; BADS; Wilson, Alderman, Burgess, Emslie, and Evans, 1996). Likewise, Giesbrecht and co-workers (2004) noted that in a healthy undergraduate sample dissociative symptoms were linked to certain aspects of the RNG task (cf. supra). With these findings in mind, we believe that research on the associations between traditional personality traits (e.g., dissociation), executive functions (e.g., cognitive inhibition, working memory), and pseudo-memories might be informative. Having said this, we also believe that two potential limitations of this research domain deserve some comment. First, the term "executive function" is often used in a broad way and our use of this concept throughout the chapter is no exception to this rule. Clearly, research on the neuropsychology of pseudo-memories would benefit from a more articulated definition of this key concept (see also Miyake, Friedman, Emerson, Witzki, Howerter, and Wagner, 2000; Friedman and Miyake, 2004). Subdividing the concept of "executive function" in different well-defined subcomponents like cognitive inhibition, monitoring, updating, would be a first step. Secondly, the term pseudo-memory has been used in a liberal way too. Thus, increases in subjective confidence, confabulations, and false alarms on recognition tasks have all been treated as manifestations of pseudo-memories. But, again, this domain would benefit from a stricter definition of what counts as a full-blown pseudo-memory (see Smeets et al., 2005).

BH Again

Our patient BH had evident signs of right prefrontal damage. Unfortunately, these signs were disregarded by the psychiatrists who treated him. These clinicians were preoccupied by his retrograde amnesia. BH had great difficulties to retrieve accurate and detailed memories about his childhood and, in fact, he was unsure about his identity. Meanwhile, the police required complete information about his age and his place of birth, so as to provide him with legal documents. Encouraged by the police, BH first underwent a series of hypnosis sessions avid subsequently treatment with the "truth serum" pentobarbital. During the hypnosis and pentobarbital sessions, the psychiatrists interviewed him. Their questions were based on the assumption that BH had a military background. Hence, BH was asked about military training, secret missions, parachutes, weapons, the U.S. army, Russia, and many related themes. It is not too farfetched to say that the psychiatrists combined post-hoc misinformation, imagination inflation, and semantic-relatedness techniques during their interviews. That this was not without effect became clear when BH began to uncover memories about his Canadian background and his work as a CIA agent. Although these memories were detailed and compelling, they turned out to be full-blown pseudo-memories. By coincidence, the police was able to establish the real identity of BH. He was born in a Paris suburb and had never been to Canada or the US. One day, he became involved in a fight, during which he was badly injured. To this very day BH prefers to believe that he is a Canadian who worked for the CIA rather than a Parisian who one day decided to visit Amsterdam.

Author Notes

This review and the described studies by the first author were supported by a grant from the Dutch organization for scientific research N.W.O. grant number 452-02-006.

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