MEMORY FOR OBJECT LOCATIONS IN KORSAKOFF'S AMNESIA*

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Abstract

Deficits in spatial context memory are an important characteristic of Korsakoff's amnesia. In memory for spatial context information, there is evidence for a functional dissociation of three separate processes: (1) binding of object information to locations (i.e. binding complex memories), (2) exact, metric processing of Euclidean co-ordinates, and (3) an integration mechanism. In the present study, these sub-mechanisms were assessed experimentally in a group of Korsakoff patients (N = 20) and compared to healthy controls (N = 20) to see whether selective deficits can be demonstrated. It was found that Korsakoff patients display deficits on all three spatial-memory conditions, which are not the primary result of deficits in visuo-spatial construction and memory for object identity. No evidence for selective impairments could be observed. These impairments can be linked to damage of diencephalic regions and perhaps the parietal cortex.

Key words: spatial memory, Korsakoff's syndrome, amnesia

Introduction

Korsakoff's syndrome, which can develop in chronic alcoholics, is characterised by severe cognitive dysfunction, which has been linked to frontal-lobe pathology as well as to damage of the region of the mammillary bodies in the diencephalon, probably as a result of chronic thiamine deficiency (Joyce, 1994; Langlais and Savage, 1995; Mayes, Meudell, Mann et al., 1988; Sziklas and Petrides, 1997). Recently, these brain areas have been studied more thoroughly using neuroimaging techniques. For example, dysfunction of the anterior diencephalic area that is specific for alcoholic Korsakoff patients was demonstrated using structural MRI (Jernigan, Schafer, Butters et al., 1991), whereas the posterior diencephalic region was abnormal both in Korsakoffs and alcoholic controls. Others (Blansjaar, Vielvoye, Van Dijk et al., 1992) suggest that next to diencephalic damage, temporal-lobe lesions may account for the memory problems seen in patients suffering from Korsakoff's syndrome, but a recent PET study did not find evidence for temporal or hippocampal dysfunction (Paller, Acharya, Richardson et al., 1997). Moreover, frontal atrophy has been demonstrated in these patients (Benson, Djenderedjian, Miller et al., 1996; Paller et al., 1997).

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Most pronounced in Korsakoff's syndrome are the severe memory deficits, both for recent and for remote information (Butters, 1985). Also, problems can be seen in executive functioning (Pollux, Wester and De Haan, 1995), attention (Oscar-Berman and Bonner, 1989), visuo-perception (Kapur and Butters, 1977), and visuo-spatial construction (Butters, 1985). The intellectual ability, however, may be preserved, as well as procedural learning (Mayes and Downes, 1997). Typically, working memory is also relatively intact (Haxby, Lundgren and Morley, 1983; Joyce and Robbins, 1991), but severe anterograde and retrograde amnesia has been demonstrated in these patients. Although Korsakoffs have massive general memory problems, evidence can be found in the literature that these patients may have additional problems in remembering spatial information, such as spatial probability learning (Oscar-Berman, Sahakian and Wikmark, 1976), spatial reversal learning (Oscar-Berman and Zola-Morgan, 1980), maze learning (Nissen, Willingham and Hartman, 1989), spatial delayed response performance (Oscar-Berman, Hutner and Bonner, 1992), and priming of spatial configurations (Verfaellie, Milberg, Cermak et al., 1992).

In line with these findings, it has been suggested that patients suffering from Korsakoff's syndrome have particular problems with memory for contextual information, such as spatial or temporal relations between stimuli (Mayes, 1988; Mayes, Meudell and Pickering, 1985). Kovner, Dopkins, and Goldmeier (1988), for example, demonstrated a lower performance in Korsakoff amnesics compared to controls when tested for the memory of location for line drawings in a 2×2 grid. Memory for temporal information was also impaired in these patients. Others also found disproportionate deficits on memory tests for the location of words (Mayes, Meudell and MacDonald, 1991), the location (top or bottom) of pictures on cards (Kopelman, Stanhope and Kinksley, 1997), and the location of pictures of objects in a 7×7 grid (Shoqeirat and Mayes, 1991). This had led to the so called context-memory deficit hypothesis (CMDH): the deficits in memory for target information in Korsakoff's amnesia are caused by a more primary inability to encode, store or retrieve contextual information. Further corroborating the CMDH, it appears that context-free memory is relatively spared in Korsakoff's syndrome, in contrast to disproportionate and qualitatively different impairments in context memory (see Mayes et al., 1985, for a review).

It should be mentioned that disproportionate spatial-memory deficits are not always reported. In a study by MacAndrew and Jones (1993), Korsakoff amnesics had to learn and recall the locations of 16 small toys on a table. Here, differences were found between Korsakoffs and healthy controls, but no evidence was found for disproportionate spatial memory disturbances. Chalfonte, Verfaellie, Johnson et al. (1996) also failed to demonstrate disproportionate deficits in Korsakoff's amnesia on a test for the location of 30 pictures in a 7×7 grid. Differences in the tasks and methods could potentially account for these contrastive findings. For example, testing object-location memory with a grid enables the use of verbal encoding strategies (Postma, 1996; Postma and De Haan, 1996). Also, there are differences between the nature of the stimuli used – words, small or large line drawings, or small toys – and the number of presented stimuli. Moreover, there may be various sub-processes within object-location memory that could yield different findings (Schacter and Nadel, 1991).

In this light, Postma and De Haan (1996) proposed a dissociation of two processes that are important here. First, information about the identity of the objects has to be linked to their locations (i.e. the concept of binding). Second, in order to remember the locations of these objects, the exact, Euclidean co-ordinates of stimuli have to be encoded. In addition, as suggested in Postma, Izendoorn and De Haan (1998), a third process might exist that integrates metric encoding per se and the binding of item and location information. This process is most commonly tested in spatial-memory experiments: What is where in our environment? (cf. Smith and Milner, 1981, 1989).

A paradigm has been developed with which these three processes could be measured. To assess binding of objects to locations, subjects are shown different items on different locations. Subsequently, these have to be relocated to their previous positions, which are pre-marked by dots. Positional encoding is tested by means of a display with identical objects on different locations without pre-marked positions in the relocation phase. Finally, the integration process is assessed by a display with different objects at different positions, again without pre-marked locations (Postma and De Haan, 1996; Postma et al., 1998; Kessels, Postma and De Haan, 1999). Using this paradigm, convincing evidence for a functional dissociation has been found using articulatory suppression (Postma and De Haan, 1996). Here, verbal interference especially affected the condition in which subjects had to relocate nonsense or letter stimuli to pre-marked positions, whereas positional reconstruction was not or to a lesser extent (see experiment 3 of Postma and De Haan, 1996). Other studies – using pictures of everyday objects as stimuli – demonstrated that males performed better than females in the positional encoding condition only (Postma et al., 1998), and that performance on positional reconstruction varied as a result of hormonal changes during the menstrual cycle (Postma, Winkel, Tuiten et al., 1999). The combined condition was selectively affected by testosterone administration (Postma, Meyer, Tuiten et al., submitted). Moreover, restricted effects on the various components of object-location memory have been demonstrated in patients suffering from ischaemic stroke (Kessels, Postma and De Haan, 1998).

In the light of the foregoing, the goal of the present study was to further examine the nature of spatial context deficits in Korsakoff patients. Rather than focusing upon whether context memory is disrupted more than target memory, we focused upon the precise characteristics of the spatial context disorders: Are certain aspects of object-location memory impaired, while others are not? If selective deficits could be demonstrated in this patient group, this would provide additional evidence for a dissociation of the aforementioned processes within object-location memory. One might speculate that it is in particular the process of binding that is selectively impaired in Korsakoff patients, since this relies upon binding or associating different attributes in memory, such as the colour, identity or spatial location of previously encountered items (Johnson and Chalfonte, 1994; Chalfonte and Johnson, 1996). Associative memory was found disproportionally impaired in Korsakoff patients (Shoqeirat and Mayes, 1991). Chalfonte et al. (1996) suggested that this could result of dysfunction in a hippocampal-diencephalic binding circuitry.

Notwithstanding that it was not our purpose to compare target memory and context memory, it is of course possible that spatial memory deficits are a side effect of a general memory disorder. To account for this possibility, an object-recognition test was included in order to evaluate the contribution of general memory dysfunction in Korsakoff patients. Likewise, the spatial memory performance may be influenced by a deficit in visuo-spatial construction. Therefore, a test for visuo-spatial construction was also used.

Materials and Methods

Subjects

Twenty chronic Korsakoff patients participated in this study (16 males, 4 females), who received treatment at the Korsakoff Clinic of the Vincent van Gogh Institute, Venray, The Netherlands. Neuropsychological data were available for 15 of these patients, as 5 patients refused further neuropsychological testing. Intelligence as measured with the Wechsler Adult Intelligence Scale (WAIS) was in the normal range for the neuropsychologically tested patients. Memory was severely affected in these patients. Verbal memory was assessed with the Rey Auditory Verbal Learning Test (RAVLT). Ten patients scored in the first, 3 in the second, 1 in the third, and 1 in the fourth decile. Non-verbal memory and visuo-spatial construction was assessed with the Rey-Osterrieth Complex Figure Test: all patients scored below the tenth percentile here (Table I summarises the results of the neuropsychological tests). Twenty healthy subjects that were matched for age and educational level (16 males, 4 females) were used for control purposes.

Both the Korsakoff and the control group completed a Dutch version of the Annett Handedness Inventory (described in Briggs and Nebes, 1975): mean score for the patients was + 16.9 (SD = 14.2), mean score for the controls was + 12.5 (SD = 17.6). The educational levels of all participants was recording using 7 categories, 1 being the lowest education, 7 the highest (mean education for the patients was 4.1, SD = 1.2; mean education for the controls was 4.2, SD = 1.5). Mean age for the patients was 48.3 (SD = 4.6), for the control group 51.7 (SD = 8.0). No significant group differences in age, $t(38) = 1.67$, educational level, $t(38) = 0.23$, and handedness, $t(38) = 0.86$, were found.

Apparatus

All stimuli were designed using the program Object Relocation (Kessels et al., 1999) on a personal computer. The stimulus displays were presented on a 17’’ monitor (Philips 17A Brilliance) including a touch-sensitive screen (AccuTouch 2201 PC-Bus). The stimuli that were presented were coloured pictures of everyday, easy-to-name objects (size approximately 1 × 1 cm). For the spatial-memory conditions, the objects were presented

TABLE I

Neuropsychological Test Scores for the Korsakoff Group (mean and SD)

	Mean	SD
Rey Auditory Verbal Learning Test – immediate recall	25.00	6.18
Rey Auditory Verbal Learning Test – delayed recall	1.07	1.58
Rey Auditory Verbal Learning Test – delayed recognition	11.33	2.50
Rey-Osterrieth Complex Figure Test – copy	25.97	6.13
Rey-Osterrieth Complex Figure Test – delayed recall	4.33	3.73
Total IQ (WAIS)	94.87	15.16

Note. N = 15 (5 patients refused further neuropsychological testing). There were no statistically significant differences between the 15 patients with and the 5 patients without neuropsychological test results with respect to age, education or handedness. Furthermore, leaving out the patients without test data did not produce different results on all other analyses reported in this paper.

within a 19×19 cm frame. In the so called visuo-spatial construction condition, two frames were present at the same time with a frame size of 15×15 cm. The objects were evenly distributed across the frame in the spatial-memory and visuo-spatial construction conditions; in an object-alone memory condition, recognition memory for object identity was tested. Here, the objects were displayed within a 5×2 grid (size 19×5 cm). All stimuli were presented on a grey background. Across all trials, different sets of objects and different spatial layouts were used.

Procedure

The conditions were presented to each subject in a fixed order. The experiment started with the object-memory condition. Ten different objects were presented for 30 s. Hereafter, the frame was emptied and the objects reappeared on top of the screen, mixed with 10 distracter items. Now, the subject had to select the 10 objects that were previously shown using the touch-sensitive screen, regardless of its original position within the grid. Next, the screen was cleared, and the subject had to select the 10 previously shown items after an unfilled delay of 180 s. Second, in the visuo-spatial construction condition, the left frame contained 10 different objects at 10 different location, whereas the right frame was empty, with the 10 objects on top of the screen. The subject's task was to copy the left frame, i.e. to assign the objects to the positions as accurately as possible.

Subsequently, in the object-to-position assignment condition, 10 different objects on different locations were presented for 30 s. In the relocation phase, these positions were marked by black dots and the objects reappeared on top of the screen. The subject had to assign each object to its previously occupied position, both immediately after the presentation phase, and again after an unfilled delay of 180 s. In the positions-only condition, 10 objects that were all equal were presented at different locations. The subject had to relocate only the correct positions (both immediately and after a delay of 180 s). Finally, in the combined condition, 10 different objects were presented at different locations. In the relocation phase, no pre-marked dots were visible, and the subject had to relocate each object to its previous position as accurately as possible (again using immediate and delayed testing after 180 s).

Each condition consisted of two stimulus displays that were subsequently presented, with a different set of objects and a different spatial layout. There were no time limits in the relocation phase. For practice purposes, the subjects were given practice trails before the actual test stimuli with only 4 objects that were presented for 20 s (with a 30 s delay).

Analyses

For the object-memory condition, the percentage of errors was determined. The percentage incorrectly placed objects was determined in the object-to-position condition. For the combined and visuo-spatial construction conditions, the absolute distance between the relocated position and the original position was computed for each object; the absolute displacement error was the total of these absolute distances in mm for the stimulus display as a whole. In the positions-only condition, all objects being equal, this could not be done, since it cannot be easily determined which object belongs to which position. Therefore, all possible pairings of relocated and original positions were computed; the best-fit measure in mm was based on the pairings which yielded the smallest error score for the stimulus display as a whole (see Postma and De Haan, 1996, and Postma et al., 1999, for a detailed discussion of these error measures).

All conditions were analysed separately by means of analyses of variance for repeated measurements (with 'delay' as within-subject factor). Between-subject factor in all analyses was 'group'. To eliminate the effects of general impairments in memory and visuo-spatial construction sec, analyses of covariance were performed for the three spatial-memory conditions. The performance on the immediate object-identity memory task and the visuo-spatial construction condition were used as covariates. In order to directly compare the three memory conditions, effect sizes were computed (Cohen's d), i.e. the standardised difference between the Korsakoff and the control group, using the immediate relocation errors.

Results

Table II summarises the results of the object-memory conditions (immediate and delayed) and the visuo-spatial construction condition. For the object-memory condition, a significant effect of delay was found [$F(1, 38) = 43.22$, $p < .0005$]. Moreover, a group effect [$F(1, 38) = 80.93$, $p < .0005$] as well as a group × delay interaction could be determined [$F(1, 38) = 24.71$, $p < .0005$]. The Korsakoff and control group also differed significantly in the visuo-spatial construction condition [$F(1, 38) = 21.24$, $p < .0005$].

TABLE II

Means and Standard Errors of the Percentage False Hits in the Object-memory Conditions (immediate and delayed), and the Absolute Error Score in mm in the Visuo-spatial Construction Condition

	Korsakoff group		Control group	
	Mean	SEM	Mean	SEM
Object memory – immediate (%)	25.25	11.29	3.00	4.97
Object memory – delayed (%)	35.25	13.01	4.25	6.34
Visuo-spatial construction (mm)	126.40	46.64	73.76	20.84

Figure 1 summarises the results for the Korsakoff and control group in the three spatial memory conditions. Analyses on the percentage incorrectly placed objects for both groups in the object-to-position condition (immediate and delayed) showed a significant effect of delay [$F(1, 38) = 6.29$, $p < .05$]. A group effect was also present [$F(1, 38) = 104.28$, $p < .0005$], but no group × delay interaction. The analysis of covariance also demonstrated a group effect [$F(1, 36) = 15.64$, $p < .0005$]. For the best-fit measure in the positions-only condition (immediate and delayed), an overall delay effect could be found [$F(1, 38) = 12.54$, $p < .001$], as well as a significant group difference [$F(1, 38) = 71.12$, $p < .0005$]. There was no interaction of group × delay. The analysis of covariance yielded a significant group effect [$F(1, 36) = 20.48$, $p < .0005$]. The absolute error score in the combined condition (immediate and delayed) yielded a significant delay effect [$F(1, 38) = 27.87$, $p < .0005$], as well as an effect of group [$F(1, 38) = 72.77$, $p < .0005$]. The group × delay interaction was not significant. The analysis of covariance also produced a significant group effect [$F(1, 36) = 19.41$, $p < .0005$].

Effect sizes were computed for the object-to-position condition ($d = 2.93$), the positions-only condition ($d = 2.41$), and the combined condition ($d = 2.61$). According to the nomenclature of Cohen (1988) these values indicate a 'large' difference. There were no significant differences between these three effect size [$\chi^2(2) = 0.65$]. In addition, it was analysed whether the performance of the Korsakoff patients was above chance level[1]. This was the case for the object-to-

[1]This was done by comparing the performance to the results of 10 healthy control subjects who were instructed to relocate the objects to the correct positions by guessing, i.e. without having seen the original displays. The identical objects and spatial layouts were used as described earlier. Mean error scores (and standard deviations) were 91.00 (8.76) for the object-to-position condition, 314.15 (49.45) for the positions-only condition, and 926.78 (43.43) for the combined condition.

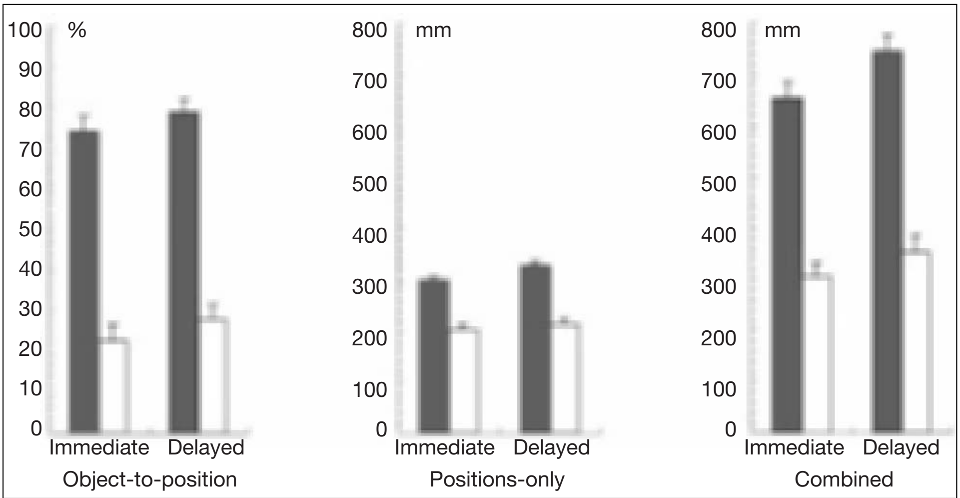

Fig. 1 – *Mean error scores (and standard errors) in the object-to-position condition (percentage mislocated objects), the positions-only condition (best-fit score in mm), and the combined condition (absolute deviation in mm) for the Korsakoff patients (■) and the control subjects (□).*

position condition [t (28) = 2.84, p < .01] and the combined condition [t (28) = 5.43, p < .0005]. In the positions-only condition, the performance did not differ from chance level [t (28) = 0.70]. The control subjects performed well above chance level for all conditions.

Discussion

The present study examined whether patients suffering from alcoholic Korsakoff's syndrome show selective deficits in memory for contextual information, more specifically in separate processes within memory for object locations. Three sub-mechanisms were studied: binding of item and location information, positional encoding and the integration of these two mechanisms. Also, memory for object identity as well as visuo-spatial constructive ability was measured. Previous studies typically examined spatial context memory in amnesia using tasks similar to the combined condition (i.e. subjects are presented a number of objects at different locations and subsequently have to relocate these objects to their correct positions). However, separate mechanisms with object-location memory have not been studied in Korsakoff amnesia. The present findings show that Korsakoff patients performed worse than age- and education-matched controls on all three spatial-memory conditions. Moreover, object-identity memory and visuo-spatial construction was disrupted in these patients compared to controls, but an analysis of covariance using these two factors still produced significant group effects on the spatial-memory conditions. Delayed performance (after 3 minutes) was worse than immediate performance in all memory conditions for both groups. Thus, multiple aspects of spatial context memory appear impaired in Korsakoff patients. They display severe problems both in memory for precise, Euclidean positions and in binding objects to locations. Also, the performance in the combined condition, requiring the integration of the other two components, is disrupted compared to control subjects.

Of further interest, it was found that patients suffering from Korsakoff's syndrome performed above chance level in the combined and object-to-position conditions, but not in the positions-only condition. This might indicate a selective finding suggesting that Korsakoff patients are extremely poor in encoding and reconstructing precise, metric positions. There were, however, no differences in effect size between the positions-only condition compared to the other two conditions. A disproportionate deficit for positional memory seems thus unlikely.

The results of the visuo-spatial construction condition show that Korsakoff patients are less accurate in positioning objects using a tough-sensitive screen than healthy subjects. This is probably due to a combination of motivational factors (cf. Oscar-Berman, 1992) and motoric problems (cf. Jacobson, Acker and Lishman, 1990), but visuo-perceptual problems can also play a role (cf. Kapur and Butters, 1977). However, although the deviations were larger than in controls, the overall spatial layout was correct (i.e. objects were positioned at approximately the correct positions within the frame). This – together with the results of the analysis of covariance – indicates that the group differences found in spatial memory cannot be explained by deficits in memory for target information and visuo-spatial constructive abilities in the Korsakoff group.

It is possible that these impairments in object-location memory are aggravated by verbal recall deficits rather than reflect spatial memory dysfunction as such. Previous research has indicated that verbal strategies may play a role in object-location memory tasks (Postma and De Haan, 1996). Since the objects that had to be remembered were easy-to-name items, the displays could be encoded by using verbal strategies. However, it is especially the object-to-position condition that benefits from this, while metric positional encoding is less vulnerable to verbal encoding strategies (cf. Postma and De Haan, 1996). Thus, it is unlikely that the effects demonstrated in this study are strongly based upon impaired verbal recall.

A further point of discussion is the extent to which sequence effects play a role, because the conditions were presented in a fixed order: object-to-position assignment, positions-only, and combined condition. That is, possible selective deficits in object-location memory might be masked by practice, resulting in a relatively better performance in the last condition (the combined condition). Similarly, and countering practice, there might be an effect of fatigue, especially in the patient group, perhaps leading to a more optimal performance in the first compared to the last task condition. We want to emphasise, however, that the fixed order of our present task is in line with neuropsychological practice, i.e. the simplest tasks were presented first, while more complex tasks were presented last. Furthermore, presenting the conditions in a random order would increase the between-subject variance and thus decrease the power of the design.

It is worthwhile to consider the involvement of specialised brain regions in the specific sub-mechanisms of spatial memory. Johnson and Chalfonte (1994), for example, state that the hippocampus is important for binding complex memories. In a study comparing patients with hippocampal damage to Korsakoff amnesics, it appeared that only the hippocampally damaged group displayed problems of item-location binding (Chalfonte et al., 1996). In our present study, the object-to-position condition can be regarded to specifically assess binding aspects. Object-identity information has to be linked to its relative spatial location, regardless of the exact, metric co-ordinate. In contrast to Chalfonte et al. (1996), Korsakoff patients performed worse on this condition compared to healthy controls. In line with the foregoing, this might thus indicate a contribution of hippocampal dysfunction to Korsakoff's amnesia. Against this possibility, it should be mentioned that hippocampal damage has yet to be convincingly demonstrated (Paller et al., 1997). An alternative account therefore might be that the hippocampus is probably not the only structure that is important in object-location binding. For example, there is evidence that the parahippocampal gyrus is equally important (Milner, Johnsrude and Crane, 1997). Furthermore, the mammillary bodies in the diencephalon, known to be damaged in Korsakoff patients, are connected via the fornix with the hippocampus (Mayes et al., 1988). Damage to the mammillary bodies might result in hippocampal dysfunction and, perhaps, impaired object-location binding.

Generally, the processing of positional information has been linked to more posterior cortical regions, such as the parietal lobes. Newcombe, Ratcliff and Damasio (1987), for example, described a dissociation between a ventral 'what' pathways and a dorsal 'where' pathway in the brain. The latter includes the parietal lobe, and damage to this area has been recently demonstrated in Korsakoff's amnesics by Paller et al. (1997). While the precise contribution of posterior regions to Korsakoff's syndrome remains unclear, the condition which is presumably most directly associated with posterior functioning – the positions-only condition – appeared clearly impaired in this study.

Frontal atrophy has also often been linked to spatial deficits in Korsakoff's amnesia (e.g. Joyce and Robbins, 1991). The frontal lobes, however, are especially important in working memory in general, as well as in memory for temporal relations (i.e. serial learning), and not so much in pure spatial processing (Kopelman et al., 1997; Squire, 1982; Kessels, Wijnalda, Postma et al., submitted). This explains why maze learning is often found impaired in Korsakoff patients, since this loads upon working-memory processes as well as upon temporal learning. In the object-location memory task used in the present study, objects were presented simultaneously to eliminate possible effects of deficits in serial learning. In addition, we tested both immediate and delayed relocation in order to control for a dysfunction in working memory, which be especially noticeable in the immediate relocation. The current results, however, showed that delayed test performance was worse than immediate memory, which indicates that the spatial deficits in Korsakoff patients are not solely the result of a working-memory impairment.

In sum, we demonstrated that the disruption of spatial memory in Korsakoff's amnesia extends to (1) object-location binding, (2) exact, metric encoding, and (3) an integration of these two processes. No evidence was found for selective impairments within memory for object locations. These deficits can be linked to relatively widespread damage to diencephalic regions (including the mammillary bodies) and perhaps the parietal cortex.

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