SPATIAL COGNITION AND COMPUTATION, *7*(3), 287–309

Dysfunctions of Spatial Cognition in Schizophrenic Patients

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ABSTRACT

Twenty outpatients who fulfilled the criteria for a diagnosis of schizophrenia and 28 control participants were invited to learn a route through a complex outdoor environment. They were then tested in tasks intended to explore various aspects of their memorized representation of the navigational episode. Compared to controls, the patients showed significant impairment in both the verbal production of route directions and the drawing of sketch maps. They referred to fewer landmarks and provided fewer directional instructions than the controls, while making a greater number of irrelevant comments. When invited to distinguish between photographs showing views of landmarks encountered along the route and distractors, they performed as well as the controls, and they had similar response times. However, when they were presented with pairs of actual photographs taken along the route, they displayed special difficulty in deciding which of the two landmarks was encountered first along the route. This difficulty in retrieving the sequential structure of the navigational episode suggests that the patients' memories were not accurately linked to one another in their mental representation of the route. These findings are interpreted in the context of current hypotheses about the hippocampal impairment that affects schizophrenic patients.

Keywords: hippocampal deficit, navigation, route directions, schizophrenia, sketch maps, temporal information

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1. INTRODUCTION

It is commonplace to highlight the breadth of the scope of contemporary research on spatial cognition (e.g., Denis & Loomis, 2007). This situation results from the variety of spatial environments to which human cognition is applied, from small-sized configurations typically used to test individual spatial abilities, to large-scale navigable environments. It also results from the variety of environmental contexts for human spatial performance and of the behavioral indicators of spatial capacities (locomotion, pointing, judgments of relative directions, wayfinding, map drawing, spatial discourse, to mention just a few) (see Allen, 2003; Daniel, Tom, Manghi, & Denis, 2003; Gillner & Mallot, 1998; Hegarty, Montello, Richardson, Ishikawa, & Lovelace, 2006; Hirtle & Mascolo, 1986; McNamara, Rump, & Werner, 2003; Noordzij & Postma, 2005; Shelton & McNamara, 2004; Tversky, 2000).

As in any other domain of cognition, significant progress has been made possible by studying how these capacities develop (e.g., Siegel & White, 1975), but also by investigating dysfunctions of these capacities in adults, and how people suffering from specific cognitive or sensory deficits compensate for them and develop adequate navigational strategies (e.g., Loomis, Marston, Golledge, & Klatzky, 2005). A special interest has developed in disorders affecting the cognitive mechanisms that support navigation and spatial orientation. Among the neurological disorders that most commonly affect spatial cognition, dementia of the Alzheimer type is undoubtedly the one that has received most attention as a result of its severe impact on spatial orientation and spatial representation (cf. Denis, Ricalens, Baudouin, & Nespoulous, 2006; Passini, Rainville, Marchand, & Joanette, 1995; Ricker, Keenan, & Jacobson, 1994). Another valuable source of information about spatial cognition and spatial language is available in the characteristic features of spatial discourse of the patients with Williams syndrome (cf. Hoffman, Landau, & Pagani, 2003; Landau & Lakusta, 2006).

In the neuropsychological domain, the disorders resulting from parietal lesions have been shown to affect not only perceptual and navigational behavior, but also the production of spatial language (cf. Bisiach, Brouchon, Poncet, & Rusconi, 1993; Della Sala, Logie, Beschin, & Denis, 2004; Denis, Beschin, Logie, & Della Sala, 2002; Guariglia & Pizzamiglio, 2006). This domain has greatly contributed to documenting the distinction between the "what" and "where" components of spatial cognition, and to enhancing our knowledge of their cerebral counterparts (e.g., Landau & Jackendoff, 1993). Last, highly relevant information is available from the study of psychopathological syndromes related to space, such as spatial anxiety and agoraphobia (e.g., Capps & Ochs, 1995; Viaud-Delmon, Siegler, Israel, Jouvent, & Berthoz, 2000).

The investigation of the cognitive deficits associated with psychiatric syndromes has been a flourishing area of research over the past decade, especially in schizophrenic patients. However, there is still little information available about the impact of psychiatric dysfunction on spatial cognition. The best-documented cognitive deficits in schizophrenia are those affecting the attentional resources, executive control, and working memory capacities of patients (e.g., Braff, 1993; Green, 1996; Morris, Rushe, Woodruffe, & Murray, 1995; Saykin et al., 1991, 1994). These deficits are generally thought to reflect prefrontal cortex dysfunction. More specifically, severe impairment of visuospatial working memory has been reported in schizophrenia.

Schizophrenic patients perform especially poorly in tasks requiring a representation of a visual stimulus to be maintained before generating a response (cf. Carter et al., 1996; Gooding & Tallent, 2004; Leiderman & Strejilevich, 2004; Park & Holzman, 1992, 1993; Park, Holzman, & Lenzenweger, 1995; Stratta et al., 1999). This is particularly true when the patients have to maintain the internal representation of a moving target. They have special difficulty in recognizing visual objects or predicting their trajectory in a spatial environment (cf. Hooker & Park, 2000). The processing of spatial serial orders, in a task where the participants have to remember the locations and the order in which targets were presented, is markedly affected in schizophrenia (cf. Fraser, Park, Clark, Yohanna, & Houk, 2004; see also Dreher et al., 2001).

There is very little information, if any, available about the deficits affecting schizophrenics' performance involving navigation or environmental knowledge, beyond the classic tasks tapping into the patients' visuospatial working memory capacities. There are, however, good reasons to expect that difficulty in processing spatiotemporal contexts will impact on the domains of spatial orientation and representation in these patients. This is an issue amenable to empirical investigation. A further motivation for such investigation lies in the fact that hippocampal deficits have been amply documented in schizophrenia (see Harrison, 2004, for a review).

These deficits are reflected by a number of indicators, such as the reduction in the total volume of the medial temporal lobe, in particular of the hippocampus (cf. Gothelf et al., 2000; Heckers, 2001; Nelson, Saykin, Flashman, & Riordan, 1998; Velakoulis et al., 2001). Also well established in schizophrenia are the cytoarchitectural alterations in the hippocampus (Arnold, Hyman, Van Hoesen, & Damasio, 1991; Jeste & Lohr, 1989), the decrease in the size of the pyramidal neurons (Arnold et al., 1995; Conrad, Abebe, Austin, Forsythe, & Scheibel, 1991), and a variety of glutamatergic abnormalities (Gao et al., 2000; Ibrahim et al., 2000; Meador-Woodruff & Healy, 2000).

If schizophrenics have an impaired hippocampal function, then there are grounds for suspecting that the forms of spatial behavior that are regulated by the hippocampus will show specific impairment in these patients. This expectation is also based on the neuroimaging studies that have documented the role of the hippocampus in the acquisition of spatial information (Aguirre, Dettre, Alsop, & D'Esposito, 1996; Maguire, Frackowiak, & Frith, 1996; Maguire et al., 2000) and in mental navigation (Ghaëm et al., 1996; Mellet et al., 2000, 2002). If schizophrenic patients are tested in tasks involving memorizing large-scale navigable environments, one could expect to be able to assess the putative impact of this disorder on spatial memory. This was the objective of the study reported here, which consisted of testing schizophrenics in spatial memory tasks following a navigational experience.

We selected four tests from among the wide range of spatial tests available in order to keep the experimental session within the time limits compatible with the patients' capacities. The participants had first to learn a route through a complex outdoor environment. The first two memory tests they underwent involved verbal and graphic externalizations of their spatial memory. The generation of verbal route directions is a widely used method, which makes it possible to identify some aspects of the representation of the route and its proximal environment (Daniel & Denis, 2004; Golding, Graesser, & Hauselt, 1996; Michon & Denis, 2001; Schneider & Taylor, 1999). Speech is used as a mediator to access a person's internal representation.

As long as language capacities have not severely deteriorated, they can be used to reflect an internal representation and assess whether this representation has been well preserved or has deteriorated (cf. Denis, Ricalens, Baudouin, & Nespoulous, 2006). Route directions are especially interesting in that they are based on the selection of landmarks perceived as relevant and useful. Some landmarks are identified as more significant than others, for instance when they are located close to a reorientation point. Will schizophrenic patients show the same selectivity than other people as regards these critical items? It has also been well established that the content of route directions is a composite mix of descriptive and prescriptive components. Would patients divide their discourse between descriptions and prescriptions as control participants typically do? Furthermore, beyond these specificities, would the overall amount of information used be similar in both populations?

The other means of assessing spatial memory that we used here was the drawing of a sketch map. Maps contain some of the same items of information as verbal directions (cf. Tversky & Lee, 1998). In the present context, they are of interest because they free the person from the cognitive cost of translating an internal spatial representation into the form of a structured linguistic output. Drawing a sketch map thus circumvents the language difficulties that may afflict some patients. However, it is still true that both verbal directions and maps are natural outputs generated in a context of communication, and are intended to convey the items of information that are judged to be relevant to helping another person build an accurate representation of the route and the environment. This context is a sensitive one, which should reveal the specific difficulties experienced by the patients.

Two further tests were used with the aim of measuring the memory of the learned route without any retrieval cost. One of these tests used the recognition memory of scenes encountered along the route. This is a classic method involving a task which would not be expected to result in any particular difficulties for the patients. However, the other test involved identifying the sequence in which two scenes occurred along the route. We have already pointed out that in visuospatial memory tests, schizophrenics experience special difficulty in executing tasks that require holding time-related information of visual events in the transient memory, such as visual targets in motion (cf. Hooker & Park, 2000). In a memory task following a navigational episode, one could expect that recognizing the temporal sequence of scenes would be more difficult for patients than for control participants.

The participants in the present experiment were subjected to this set of four tasks in a fixed sequence. The tasks were presented after a learning phase which allowed the participants to get acquainted with an environment during a navigational episode controlled by the experimenter.

2. METHODS

2.1. Participants

A group of 20 outpatients (6 female, 14 male) who fulfilled the criteria for a DSM-IV diagnosis of schizophrenia took part in the study. Clinical diagnoses were made by an experienced psychiatrist. All the patients had presented with a stable clinical state for the past 3 months, and there had been no change in their medication (neuroleptics) during this period. The inclusion criterion was the presence of a schizophrenic disorder, regardless of its subtype. Patients presenting with a schizo-affective disorder were excluded, as were those with a comorbid affective disorder. The sample included 5 patients with a disease onset before age 16, and 15 patients with a disease onset between 18 and 19 years of age. The exclusion criteria were as follows: history of a head injury, brain damage, stroke, an associated neurological disorder, a history of drug abuse, and changes in medication during the past three months. The mean age of the patients was 20.8 years ($SD = 3.7$). Their mean educational level was 12.0 years ($SD = 2.0$).

A group of 28 control participants (6 female, 22 male) with no history of mental disorder was recruited through public advertisement or personal contact. Their mean age was 21.7 years ($SD = 7.7$), and they had a mean educational level of 12.6 years ($SD = 2.7$). These values were not significantly different from those of the patients' group. The control participants were assessed using the Mini International Neuropsychiatric Interview (MINI, French Version 5.0.0) in order to rule out the presence of psychiatric illness in this group.

2.2. Setting and Route

The experiment took place on the premises of a Paris hospital, the Hôpital de la Salpêtrière. This ancient hospital resembles a small city extending over

33 hectares, with a number of main streets, alleys, cross junctions, squares, gardens, and includes both old and more recent buildings of various architectural styles.

A route in this environment was designed for the purpose of the experiment. The route was entirely out of doors, and an 800-meter closed loop. It started from the front door of a building, the Clérambault Pavilion, and ended behind this building. The route comprised eight interconnected segments, and walking round it involved a total of seven direction changes. Figure 1 shows a map of the Hôpital de la Salpêtrière and indicates the route.

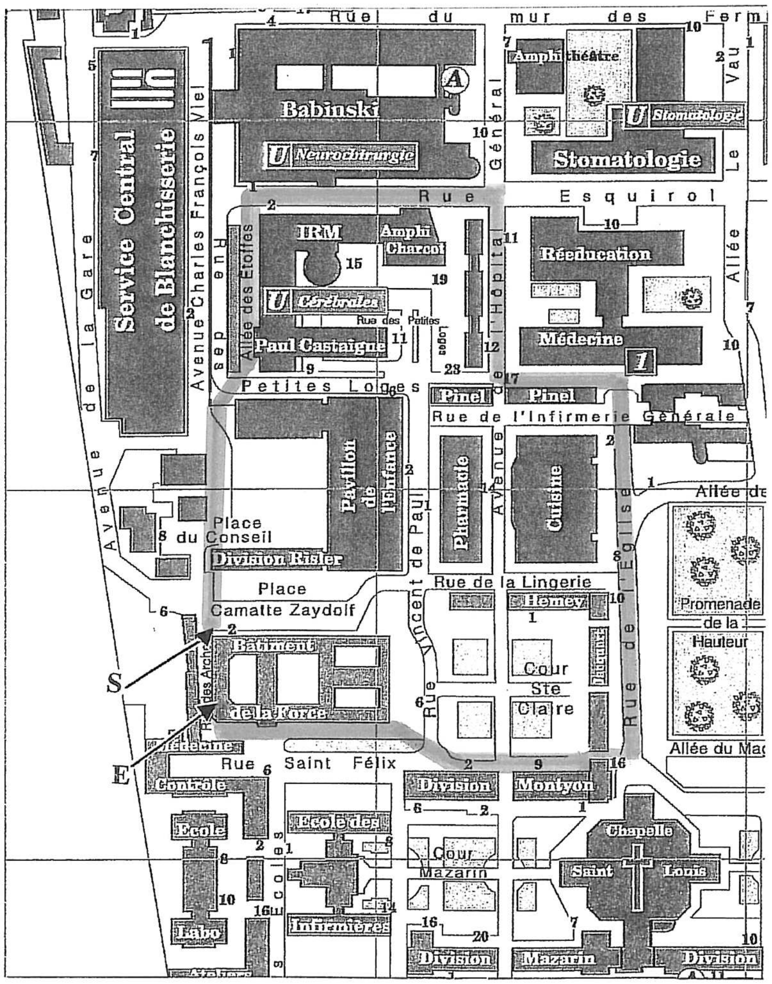


Figure 1. The setting of the experiment and the route followed by the participants (S, starting point; E, ending point).

2.3. Procedure

The participants were examined individually at every step of the experimental procedure.

2.3.1. Learning

The learning phase involved the participants' walking along the route through the hospital environment. They were accompanied by a female experimenter (CM). They were asked to pay attention to the route, and were informed that they would have to describe it to someone else later. Their description was to be as accurate as possible in order to help this person to follow the route easily. The participants were also informed that they would walk along the route twice. The time taken to walk the route once was about 10 minutes. As soon the first route walk had been completed, the second was started. The participants were then led to an office inside Clérambault Pavilion, where they performed the four experimental tasks in succession.

2.3.2. Task 1: Generating Route Directions

The participants were invited to describe the route they had just followed. They were invited to be as accurate as possible so that a person listening to the description would be able to follow the route without making any mistakes. The descriptions were recorded on tape.

2.3.3. Task 2: Drawing Sketch Maps

The participants were then given a sheet of A4 paper, and asked to draw a sketch map of the route. The instructions invited the participants to imagine that someone coming to the hospital for the first time would have to follow this route. The sketch of the route should be as accurate as possible, so that this person would be able to find the route with only the help of the map. The participants were invited to include every landmark that they thought would be helpful for this purpose.

2.3.4. Task 3: Recognizing Scenes Seen on the Route

The participants were presented with a total of 32 color photographs of the hospital environment. Sixteen of these photographs had been taken along the experimental route. They had been taken from the viewpoint of a pedestrian walking the route. There were two photographs taken from each segment, from the points which marked the end of the first and second thirds of the segment, respectively. There were another 16 photographs taken in the same hospital environment, but showing scenes that would not be visible to a person walking along the route. The full set of 32 photographs was shown to the participants on a computer screen in a random sequence. The participants were informed that some of the photographs showed scenes along the route, whereas others did not. They were instructed to press a key on the right side of the keyboard if they recognized the scene as belonging to the route, and a key on the left side if they did not. They were invited to press a key as soon as they had made their decision. Response times were recorded by the experimental device.

2.3.5. Task 4: Recognizing the Order of Scenes

The participants were presented with a succession of 28 pairs of photographs in a random sequence. The photographs of the two scenes constituting each pair were shown side by side on the computer screen. All the scenes were visible from the experimental route. They corresponded to the first photographs taken along each of the eight segments. Combining all possible pairs of photographs, there was a total of 28 pairs of scenes. The participants were informed that one of the scenes in each pair had been encountered along the route before the other one. If they identified that the scene shown on the left side of the screen had been encountered first, they were to press the key on the left side of the keyboard. If they thought that they had encountered the scene shown on the right side first, then they were to press the key on the right side. The participants were invited to press a key as soon as they had decided. Response times were recorded by the experimental device.

3. RESULTS AND DISCUSSION

3.1. Task 1: Generating Route Directions

Individual protocols were transcribed and coded using the method developed by Daniel and Denis (2004). The method involves re-expressing the protocols in terms of minimal units of information combining a predicate plus one or two argument(s). Coding was done by two of the authors (MPD and CM). The coders were blind as to whether the people who had generated the route directions were patients or control participants. If coding discrepancies arose, these were settled after consulting a third coder (MD).

The units of information were divided into five classes, following the method used in previous analyses of route directions (Daniel & Denis, 2004; Michon & Denis, 2001):

Class 1: Prescription of an action without any reference to a landmark ("*Go straight on*");
Class 2: Prescription of an action with reference to a landmark ("*Turn left before the archway*");

Class 3: Reference to a landmark without any prescription of an action ("*There is a chapel in front of you*");
Class 4: Description of a landmark ("*The benches are made of stone*");
Class 5: Comment ("*It's a nice trip*").

Table 1 shows the average number of units of information of each class produced by the participants. Overall, there were significantly more units in the descriptions produced by control participants than in those produced by patients, 60.8 (SD = 36.61) vs. 33.8 (SD = 19.96), respectively, $F(1, 46) = 8.53$, $p < .005$. The greater richness of the protocols produced by the control participants was confirmed for all classes of items ($p < .01$ or less), with the exception of Class 5, where patients generated more comments. Not surprisingly, the patients' comments often included statements of limited relevance in terms of navigational assistance (for instance, "*The trees have nice colored leaves*"). Overall, comments accounted for 8% of the protocols generated by control participants vs. 20% of those generated by patients. This was a statistically significant difference, $F(1, 46) = 6.97$, $p < .02$.

In an attempt to obtain a sharper distinction between the prescriptive and the descriptive parts of the protocols, the data for Classes 1 and 2 were pooled to reflect the amount of discourse intended to prescribe actions, and those for Classes 3 and 4 were also pooled, to reflect the amount of discourse devoted to describing landmarks. This analysis confirmed that the greater richness of the verbal protocols generated by control participants was true for both these components, 27.1 (SD = 11.61) vs. 14.9 (SD = 10.01), $F(1, 46) = 14.03$, $p < .001$, and 28.6 (SD = 23.99) vs. 12.1 (SD = 10.84), $F(1, 46) = 7.22$, $p < .01$, respectively.

The whole set of protocols was then independently reviewed by two judges (CM and a research assistant), with the objective of evaluating their value in terms of navigational assistance. An individual protocol was classified as "good" if both judges thought that it would help a person to follow

Table 1
Average number of units of information of each class produced by the participants

	Controls	Patients
Class 1: Prescription of an action without reference to a landmark	15.1 (25%)	8.6 (25%)
Class 2: Prescription of an action with reference to a landmark	12.0 (20%)	6.3 (19%)
Class 3: Reference to a landmark without prescription of an action	16.1 (26%)	7.5 (22%)
Class 4: Description of a landmark	12.5 (21%)	4.6 (14%)
Class 5: Comment	5.1 (8%)	6.8 (20%)
Total	60.8	33.8

the itinerary and reach the final destination without getting lost. Overall, out of the 28 protocols produced by control participants, 18 (64%) were classified as "good," whereas out of the 20 patients' protocols, only 6 (30%) were classified as "good," which reveals a significant difference between the two groups, $\chi^2(1) = 4.56$, $p < .02$.

To summarize, the directions given by the schizophrenics were less rich (and thus presumably of lesser informative value to the people using them). However, when we look at the relative frequencies of prescriptive and descriptive items (among the items which contained navigation-relevant information), there was no difference between the groups, i.e., both groups produced similar proportions of items instructing the moving person what to do and describing the environment. The patients were less prescriptive than the controls, but also less descriptive. The features that essentially characterized the patients' protocols were the higher frequency of comments, and the lower perceived quality of their descriptions in terms of navigational assistance.

The poor quality of route directions generated by the patients could result from at least two factors. One is the limitation of linguistic production in this disorder, which applies to any form of discourse, and the other is the specific cognitive difficulty that the patients may experience in processing spatial information. To clarify this issue, it would be useful to find out whether a nonlinguistic expression of spatial information would also confirm the difficulty experienced by schizophrenics in retrieving spatial knowledge. This was the purpose of the next step on our investigation, where the participants were invited to externalize spatial information in the form of sketch maps.

3.2. Task 2: Drawing Sketch Maps

Sketch maps were analyzed both in terms of the overall shape of the route drawn by the participants, and in terms of their richness in landmarks. The coders were blind as to whether the people who had drawn the maps were patients or control participants.

3.2.1. Overall Shape of the Route

The route actually included a total of seven reorientations or turns. The sketch maps drawn by the control participants included an average number of 6.2 (SD = 1.52) turns, while those drawn by the patients included 4.1 such turns (SD = 2.76). This difference was statistically significant, $F(1, 46) = 11.74$, $p < .001$. The route actually formed a closed loop within the hospital environment. However, 8 of the 20 patients (40%) produced a drawing where the starting and the ending points were not related to each other. This finding shows that a large proportion of the patients did not construct an accurate representation of the overall shape of the route. Figure 2 shows an example of a map drawn by a control participant (2a), contrasted to a patient's drawing (2b).

3.2.2. Richness in Landmarks

Previous research has shown that the landmarks mentioned in verbal route directions are not evenly distributed along the route, but that they tend to be concentrated at critical points (e.g., Michon & Denis, 2001). The most important of these critical points are those where a reorientation takes place. The starting and the ending points are also critical, as is shown by the high frequency of references to landmarks toward the beginning and the end of routes. In familiar environments, however, there is no clear evidence that this happens (cf. Lovelace, Hegarty, & Montello, 1999). However, it is still true that correct reference to visible landmarks is a requisite to the effective verbal communication of spatial knowledge (cf. Denis, Michon, & Tom, 2006). However, no equivalent information seems to be available about the drawing of route maps.

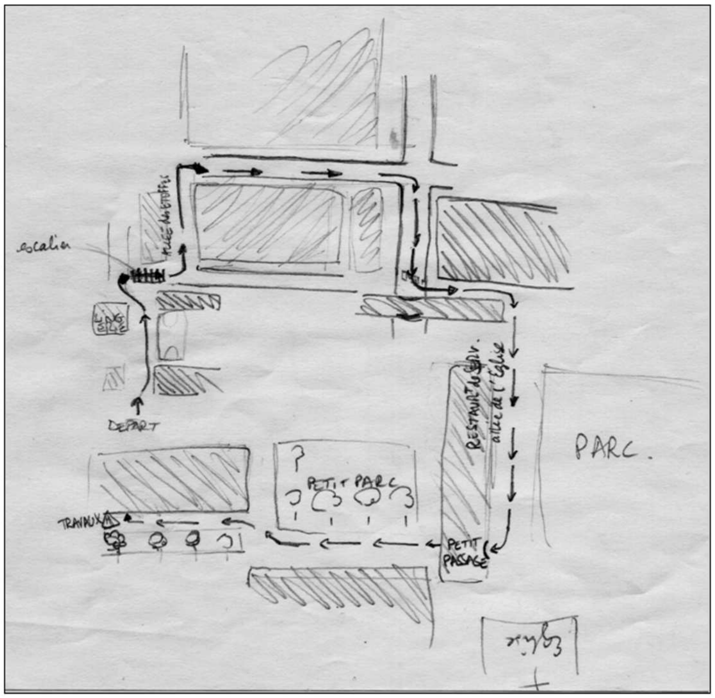
Table 2 shows the average number of landmarks included by the participants in their maps (sometimes in a very schematic form). Overall, the controls drew more landmarks than the patients, 15.9 (SD = 7.47) vs. 6.3 (SD = 5.38), respectively, $F(1, 46) = 24.60$, $p < .001$. We distinguished between the landmarks which were in the immediate vicinity of the reorientation points (within a range of 10 meters), and those which were located elsewhere along the route. The controls referred to landmarks at reorientation points significantly more frequently than the patients, $F(1, 46) = 22.21$, $p < .001$. A similar difference was found for landmarks located elsewhere, $F(1, 46) = 18.06$, $p < .001$.

A further analysis was conducted of the landmarks which were drawn by at least 12 control participants (i.e., more than 40% of them), and which were located in the immediate vicinity of the reorientation points. Table 3 shows the percentage of participants who drew each of the corresponding items in both groups. The percentage was higher for controls than for patients in all cases. Chi square tests showed that the difference was significant in all six cases ($p < .02$ or less).

As for the previous task, the whole set of sketch maps were reviewed by the same two judges. The objective was to assess the value of the maps in terms of providing navigational assistance. A sketch map was classified as "good" when both judges thought that it would provide adequate assistance

Table 2
Average number of landmarks drawn by the participants in the sketch maps

	Controls	Patients
Landmarks at reorientation points	7.3	3.0
Landmarks along segments	8.6	3.3
Total	15.9	6.3



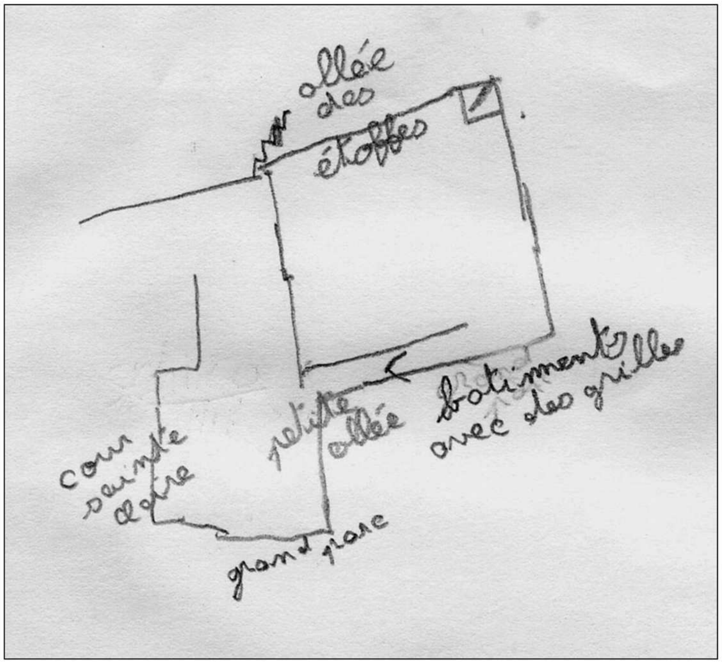
(a)

Figure 2. Examples of drawings made by a control participant (2a) and a patient (2b). (*continued*)

to a pedestrian trying to follow the route. A total of 18 of the 28 protocols produced by the control participants (64%), but only 6 of the 20 protocols produced by the patients (30%), were classified as "good." These values are similar to those for Task 1, although a few of the participants who gave good verbal descriptions did not produce good sketch maps, and vice versa. We then looked at the subset of participants who were assessed as providing both good descriptions and good sketch maps. There were 14 such participants among the controls (50%), but only 5 among the patients (25%).

Finally, we calculated the Bravais–Pearson correlation between the number of units of information related to landmarks (Task 1) and the number of landmarks drawn on the sketch maps (Task 2), in each group taken separately. The correlation coefficients were $r(26) = .61$, $p < .01$, for the controls, and $r(18) = .52$, $p < .05$, for the patients. These values reflect the fact that both tasks are sensitive to common factors in representing the navigational experience of the participants.

The fact that the deficits observed in a verbal description task were also found in a task that did not call upon linguistic capacities suggests that the



(b)

Figure 2. (*Continued*).

poor quality of the patients' route directions in Task 1 cannot be attributed solely to the communication difficulties associated with schizophrenia. The sketches themselves reveal a serious difficulty in conveying information gathered from a navigational experience. The patients' limitations therefore probably originate in their difficulty in retrieving information from their cognitive representation of the environment.

Table 3
Percentages of participants who drew the most frequently mentioned landmarks at reorientation points

	Controls	Patients
Laundry	71	25
Stairs	96	70
Babinsky Building	43	10
Archway at Pinel Building	79	25
Chapel	86	45
Archway to St. Claire Square	68	30

3.3. Task 3: Recognizing Scenes Seen on the Route

Out of the 32 photographs, the average number that triggered a correct response (correct recognition or correct rejection) was 25.9 ($SD = 3.39$) for the controls vs. 24.1 ($SD = 3.54$) for the patients, which reflects a good level of performance in both groups. Recognition performance did not differ significantly in the two groups of participants. The average response times for correct responses were 3769 ms ($SD = 1344$) for the controls vs. 4102 ms ($SD = 1373$) for the patients, which was not a significant difference.

A closer analysis revealed that the controls displayed fewer correct recognitions than correct rejections, 11.8 ($SD = 2.70$) vs. 14.1 ($SD = 1.78$), $F(1, 54) = 13.02$, $p < .001$, and that patients exhibited the same pattern, 11.0 ($SD = 1.83$) vs. 13.1 ($SD = 2.48$), $F(1, 38) = 8.82$, $p < .005$. We computed d' values in order to obtain a measure of the participants' sensitivity. To do this, we used frequencies for hits and false alarms, and then converted them into d' values. The analysis showed that d' values were 1.93 ($SD = .72$) for the controls and 1.58 ($SD = .78$) for the patients. The difference was not significant, $t(46) = 1.64$, $p > .10$. Within each group, there was no significant difference between the response times for correct recognitions and those for correct rejections.

The patients' performance in the recognition task demonstrates that the representations constructed during learning had been correctly encoded, or at least in a way not different from the controls. This suggests that the limited amount of landmark recall detected in the previous two tasks was not attributable to impaired encoding, but to difficulty in accessing the corresponding representations in a demanding retrieval context.

The next step then consisted in trying to find out whether the scenes seen on the route were coded not just as individual items, but also in sequence.

3.4. Task 4: Recognizing the Order of Scenes

Out of the 28 pairs of photographs, the average number of those eliciting a correct response was 24.2 ($SD = 3.26$) for the controls vs. 18.8 ($SD = 7.17$) for the patients. The difference between the two values was significant, $F(1, 46) = 12.45$, $p < .001$. The average time taken to produce a correct response was shorter for the controls than for the patients, 3440 ms ($SD = 1192$) vs. 3963 ms ($SD = 1642$), respectively, but this difference was not statistically significant. These data show that for similar processing times, the patients performed significantly less well than the controls.

The structure of the data makes it possible to assess whether there was any systematic relationship between the participants' response times and the distance separating the two scenes shown in a pair. For the two groups of participants taken separately, the average response times were calculated for each subset of items (pairs of photographs from two successive segments, or pairs belonging to segments separated by one, two, three, four, five, or six other segments). Bravais–Pearson coefficients were then calculated. For the controls, the coefficient indicated a significant correlation between the response time and the distance separating the two scenes, $r(5) = -.92$, $p < .01$. This correlation coefficient shows that the greater the distance between the items to be compared, the more costly the comparison process (a reflection of the "symbolic distance effect"; cf. Dean, Dewhurst, Morris, & Whittaker, 2005; Denis & Zimmer, 1992). For the patients, the correlation coefficient was $r(5) = -.53$, a nonsignificant value. These findings show that the controls' representation of the route preserves the metric qualities of the learned route, and is analogical in nature.[1] In contrast, the spatiotemporal information inherent in the learned environment seems to be lost to a large extent in the representation accessible within the schizophrenics' memory.

The special difficulty experienced by the patients in this task contrasted with their performance in the previous task. The schizophrenic patients showed no measurable deficit in recognizing the scenes seen along the previously learned route, but they did experience very specific difficulty in accessing the temporal information associated with the corresponding visual events.

4. CONCLUSIONS

After learning a route through a complex spatial environment, schizophrenic patients showed clear impairment of their ability both to produce verbal route directions and to draw sketch maps. They made fewer references to landmarks and fewer references to reorientations than control participants, while making more irrelevant comments. However, they performed as well as controls in recognizing photographs showing landmarks encountered along the route, and they took similar times to do so. The patients showed special difficulty in retrieving the sequential structure of a previous navigational episode, which suggests that their memories of the route were not properly related to one another in their internal representation of the route.

One well-documented aspect of schizophrenia is impairment of the visuospatial working memory, which is classically tested in tasks where primarily vision handles the spatial aspects of the situations, without any mobility on the part of the observer. The new information provided by the present study is the disruption of spatial cognition in navigable spaces, when a patient has to re-access knowledge previously acquired in a large-scale real-world environment explored by locomotion. Our findings fit well with what we know about hippocampal impairment in schizophrenics. They are also compatible with the impairment of spatial memory following hippocampal lesions in disorders other than schizophrenia. Lastly, the results are consistent with the well-established role of the hippocampus in the most demanding forms of navigational performance (cf. Maguire, Frackowiak, & Frith, 1997). In schizophrenics, the cognitive experience developed during navigation does not enable them subsequently to reconstruct a fully consistent, accurate spatial representation.

The tasks used here measured various facets of spatial memory of environments in which the participants had to memorize the route along which they had navigated. The difficulties experienced by the patients in retrieving spatial information both in a verbal task *and* in graphic reconstruction cannot be accounted for solely in terms of a communication deficit. The difficulties are still there when language is set aside. The fact that impairment was found in both tasks also shows that it affects both spatial knowledge built from a route perspective (as expressed in verbal directions) and the expression of spatial knowledge from a survey perspective (as expressed in sketch maps) (see Mellet et al., 2000; Tversky, 2000).[2]

The spatial difficulties experienced by schizophrenics appear to be related mainly to the cognitive reconstruction of the learned environments. These are not problems related to landmark coding, since the recognition of scenes by the patients was virtually the same as by the controls. This means that images of the environment appear to be preserved in their memory, and that their visual memory per se is not affected. The final task shows that only the temporal organization of the content of visual memory is affected (and not the content itself). The reconstruction of the chronology of the landmarks is disrupted in schizophrenics, which confirms that the problem they are confronted with pertains to spatiotemporal coordination and affects the memory of the sequence in which landmarks have been encountered during the navigational episode. This is compatible with our current understanding of the role of the hippocampus in episodic memory, especially in personal memory, when it is anchored in a spatiotemporal context (cf. Eichenbaum, 2004; Eichenbaum & Cohen, 2001; O'Keefe & Nadel, 1978; O'Reilly & Rudy, 2000, 2001; Squire & Knowlton, 1995; Squire, Stark, & Clark, 2004; Vargha-Khadem et al., 1997).

The present study is only a first step in attempting to elucidate the basis for a more advanced understanding about the possible impact of hippocampal deficits on spatial cognition of schizophrenics. Obviously, more specific questions will have to be addressed, such as the respective roles of the right hippocampus, which is thought to have a primary role in wayfinding (e.g., Burgess, Maguire, & O'Keefe, 2002), and of the left hippocampus, which is known to be involved in episodic memory and autobiographical memory (e.g., Maguire & Mummery, 1999). It would also be worth investigating the patients' performance in recall-like spatial tasks (e.g., assessments of relative direction) in contrast to scene recognition. This is a relevant comparison, given the recent indications that recall (recollection) depends more on the hippocampus, whereas recognition (familiarity) depends more on the medial-temporal cortical areas (e.g., Aggleton & Brown, 2006; Yonelinas, Otten, Shaw, & Rugg, 2005). All these aspects are relevant to drawing an integrated picture of high-level spatial cognition, even though they will have to be addressed separately in future studies.

END NOTES

1. The symbolic distance literature commonly refers to the "metric" properties of visuospatial representations on which distance comparisons are executed. Strictly speaking, the term "metric" implies some numerical value combined with a unit of measurement. However, given that comparisons are executed accurately regardless of the scale of a participant's representation, the assumption of an ordinal representation of the distances (rather than the representation of precise distances) is acceptable. It would, therefore, be more appropriate to refer to the concept of "relative metrics."
2. The contrast between route and survey representations is common in the spatial cognition literature (e.g., Denis & Loomis, 2007). We are aware that drawing a sketch map generates a survey-like graphic representation, but that an accurate map can also be drawn from a route representation in the memory. In other words, people who are drawing a map do not necessarily have to have a survey representation in their mind before they draw the map. It is therefore conceivable that both a verbal description and a sketch map could be based on the same internal route representation.

AUTHOR NOTES

This research was supported in part by the European Union in the framework of the STREP Wayfinding (Contract #12959). The authors are grateful to Stephen Hirtle and three anonymous reviewers for providing valuable suggestions on an earlier version of this article.

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