

Object Exploration, Habituation, and Response to a Spatial Change in Rats Following Septal or Medial Frontal Cortical Damage

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Normal rats and rats sustaining septal or medial frontal cortex lesions were compared in experiments dealing with object exploration, habituation, and reaction to novelty (measured by renewed exploration following a spatial change). Normal rats exhibited high levels of initial exploratory activity which decreased over time. Following a spatial change, they reinvestigated both the displaced object and the nondisplaced ones. Frontal animals were similar to normal subjects with respect to their initial exploratory level and habituation pattern. However, frontal rats reexplored only the displaced object and completely neglected the nondisplaced ones. In contrast, the behavioral pattern displayed by septal rats was markedly different from that of normal and frontal animals. Septal rats had lower levels of initial exploratory activity, did not habituate over time, and failed to react to either displaced or nondisplaced objects. These results show that although the septo-hippocampal complex and the medial frontal cortex may share some common function in spatially organized behaviors, both structures have unique roles. Some hypotheses about the possible basic processes subtended by the septal area or the medial frontal cortex are briefly mentioned and discussed.

A number of studies have shown that damage to either the medial frontal cortex or the hippocampal formation in rats produces similar deficits in a variety of spatial tasks such as the Morris water maze (Kolb, Sutherland, & Whishaw, 1983; Sutherland, Kolb, & Whishaw, 1982; Sutherland, Whishaw, & Kolb, 1983) or the radial arm maze (Becker, Walker, & Olton, 1980; Sutherland et al., 1983). Although less extensively studied, septal lesions usually induce deficits similar to those of hippocampal lesions in comparable spatial tasks (see Gray & McNaughton, 1983, for a review). In view of the similarity of lesion-induced impairments following damage to either the frontal cortex or the septo-hippocampal system, several investigators have hypothesized that both structures could form a "functionally integrated system for learning and using spatial representations of aspects of environments" (Sutherland et al., 1982, p. 275; also, see Kolb, 1984). However, specific differences between the effects of lesions to each structure have also been documented (e.g., Poucet & Herrmann, 1987; Sutherland, 1985; Sutherland et al., 1983). Postoperative retention of the Morris water task, for example, is disrupted in rats with hippocampal lesions but not in rats with frontal lesions (Sutherland et al., 1983). Thus, the possibility is raised that, within the integrated spa-

tial system hypothesized above, each structure could play a specific and different role. Accordingly, the present study was aimed at further documenting the lesion-induced deficits following septal or medial frontal cortex lesions in a task requiring the acquisition and storage of spatial information.

Following habituation to an arrangement of four objects, normal rats and rats with lesions were subjected to a response-to-change test during which one object was slightly moved from its original location. Previous studies have shown that normal animals, such as gerbils, hamsters, and rats, usually react to that change by renewed exploration of the entire apparatus and/or by selective reinvestigation of the displaced object (e.g., Cheal, 1978; Poucet, Chapuis, Durup, & Thinus-Blanc, 1986; Sutherland, 1985; Thinus-Blanc et al., 1987). Such a renewal of exploration requires that some internal representation of the topographical arrangement of the objects has been formed and compared with the new arrangement. Therefore, this method may be appropriate for assessing possible differences between normal and brain-damaged animals in terms of their ability to acquire and use spatial information as well as to habituate exploratory activity over time. With respect to the latter point, results of our previous research suggest that habituation of exploration is disrupted in septal animals but not in frontal animals (Herrmann, Poucet, & Ellen, 1985a, 1985b), a result standing in marked contrast with others showing impaired habituation of exploratory hole poking in frontal animals (Kolb, 1974). Accordingly, another purpose of the present study was to ascertain whether a different measure of exploration (number and duration of contacts with the objects) would produce the same pattern of results, that is, whether the respective presence and absence of habituation in frontal and septal rats could represent some general characteristic of the behavioral patterns associated with each lesion.

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Experiment 1

Method

Subjects

The subjects consisted of 43 male Long-Evans hooded rats, approximately 120 days of age and weighing 320–390 g. All animals had served as subjects in a spatial problem solving experiment (Poucet & Herrmann, 1987) which had ended nearly 2 weeks before the start of the present study. However, the animals were naive with respect to the experimental room, objects, and procedures used in the experiment. The rats were individually housed in standard cages in the colony room on a natural light/dark cycle and were tested during the light period. They had access to food pellets and water ad lib.

Apparatus

The apparatus has been previously described (Poucet et al., 1986; Thinus-Blanc et al., 1987). Briefly, it consisted of a circular arena 105 cm in diameter, with walls 35 cm in height. Four different objects (a glass jar, a copper weight, a bowl, and a cup, the latter two objects being placed upside down) were placed 30 cm from each other so as to form a square arrangement at the center of the arena. The field was illuminated by a single 100-W bulb. The apparatus was surrounded by white curtains so that the visual environment was homogeneous except for a conspicuous striped pattern placed 35 cm above the wall of the arena near the bowl. A camera, above the apparatus, was connected to a video recorder and a TV screen.

Surgical and Histological Procedures

The surgical procedures were performed approximately 50 days before the start of the experiment. After an injection of 0.3 ml of atropine sulfate, rats were anesthetized with an ip injection of sodium pentobarbital (55 mg/kg) and placed in a Kopf stereotaxic instrument. Radio-frequency lesions were made with the following coordinates relative to the stereotaxic zero: A/P +7.5, L 0, D/V +1.0 for septal lesions; A/P +9.5, L ± 1.0 , D/V +2.5, +4.0 and A/P +11.0, L ± 1.0 , D/V +2.5 for medial frontal lesions (König & Klippel, 1963). At all placements, the electrode was heated to 70 °C for 15 s. The animals in the control group were nonanesthetized unoperated rats.

At the completion of the experiment, the animals with lesions were sacrificed with a lethal dose of pentobarbital and perfused intracardially with saline followed by 10% formalin. Brains were removed and stored in formalin. Frozen coronal sections, 40 μ m in thickness, were taken. Every fifth section was stained with cresyl violet. The size and location of the lesions were determined by microscopic examination.

Behavioral Procedures

As the animals had been extensively handled during a previous experiment, no further handling was performed. The basic experimental procedure was as follows: Each rat was brought from its home cage to the experimental room in a black-cloth-covered cage and then individually given a 3-min preliminary exploration phase in the arena, which at this point did not contain any objects. The rat was then taken back to the covered cage for 3 min while the experimenter arranged the four objects and the striped pattern. Then, each rat received six 3-min exploratory sessions, with a 3-min interval between sessions. During the first four sessions (Sessions 1–4), the objects were arranged as indicated above. During Session 5, the glass

jar was displaced about 10 cm from its initial location so that it was slightly removed from the remaining nondisplaced objects. This particular change was chosen because previous experiments have shown it to elicit strong and selective exploratory reactions in hamsters (Poucet et al., 1986; Thinus-Blanc et al., 1987). Session 6 was merely a replication of Session 5 (i.e., no further change was brought). Subjects always entered the arena at the same point, near a nondisplaced object (the cup). The possible effect of olfactory cues from the experimenter's hands caused by the manipulation of the objects during Session 5 was neutralized by the use of plastic gloves and also by touching the objects whose locations remained unchanged. Last, the apparatus was cleaned between subjects but not between sessions for a given subject.

Data Collection and Analysis

The videotape was used for counting the number of nasal contacts the animals made with each subject and measuring the time spent in contact with each object, during each session.

The total number of contacts and the total time spent in contact with the objects was averaged across individuals in each group. A repeated measures analysis of variance (VAR 3 program; Rouanet & Lépine, 1970) was carried out on these data. Surgical treatment was the between measure, with successive sessions as the within measure. The VAR 3 program provided paired comparisons and detailed analyses of the significant effects. This analysis was aimed at determining possible effects of lesion on both the habituation pattern and the overall renewal of exploration during the test session (Session 5).

In order to ascertain whether increases in exploration during the test session were due to reexploration of the displaced object, the nondisplaced objects, or both, the number and duration of contacts with the displaced object were compared with the mean number and mean duration of contacts per object by each subject with the nondisplaced objects. This calculation was usually made for Session 4 as a reference session and for Session 5 as a test session. However, a preliminary inspection of the behavioral patterns displayed on Session 5 revealed, in some instances, marked change-induced avoidance reactions leading to reduced exploration followed by enhanced activity during Session 6. Two animals from each group displayed such late exploratory reactions. In order to account for the behavior of these particular animals, Session 6, rather than Session 5, was used as the test session, again with Session 4 as the reference session. Repeated measures analyses of variance were carried out on both the number and duration of contacts for the purpose of comparing the exploratory activity levels of each group during both reference and test sessions for each class of objects (i.e., displaced vs. nondisplaced). Thus, the main derived factors were group (normal, frontal, septal), object (displaced vs. nondisplaced), and session (reference and test sessions).

Results

Anatomical Findings

Brain examination of the septal rats revealed total destruction to the medial septal nucleus and subtotal damage to the lateral and dorsal septal nuclei (see Figure 1). Some animals had minor damage to the fornix, anteromedial caudate, and corpus callosum. Finally, all rats in this group appeared to have acceptable damage to the septum and were included in the septal group ($n = 14$).

The medial frontal lesions damaged most midline frontal cortex (Kolb, 1984; Leonard, 1972). This included the medial

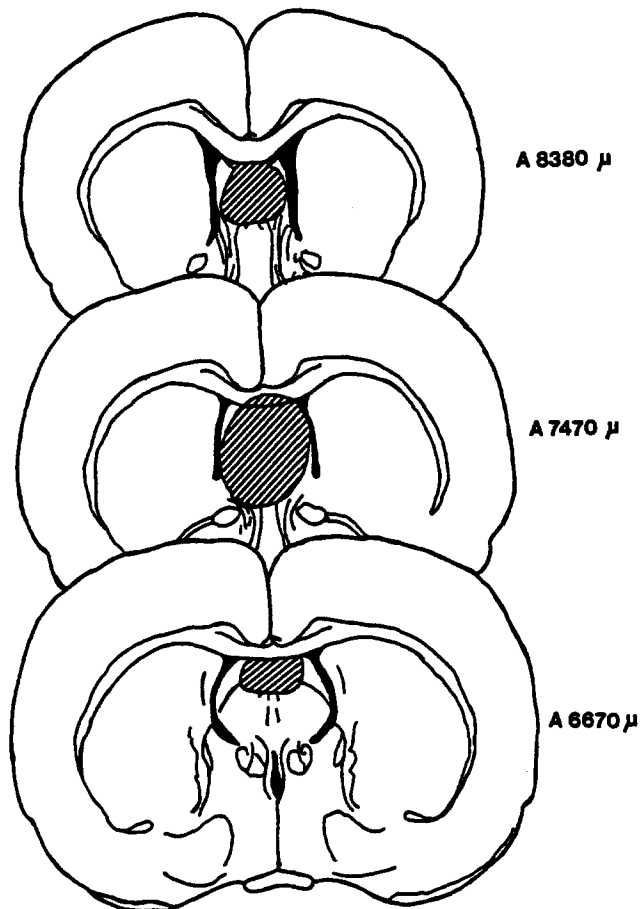


Figure 1. Schematic picture of a representative animal with a septal lesion.

precentral, dorsal anterior cingulate, and prelimbic areas. Portions of the infralimbic and ventral anterior cingulate regions were spared (Figure 2). All lesions were centered in the pregenual portion of the medial frontal cortex with no invasion to the supragenual portion. Inspection of the dorsomedial thalamic nucleus revealed subtle bilateral cell loss. Fifteen animals were considered to have acceptable lesions to the medial frontal cortex.

Behavioral Findings

The analyses respectively conducted on the number and duration of contact yielded quite comparable results concerning the main effects of group and session and their interaction. Therefore, to simplify the presentation, only the results concerning the duration of contact are presented.

Overall exploration and habituation. Figure 3 shows the mean time spent in contact with the objects, averaged across individuals of each group over the six sessions. The analysis of variance revealed a significant main effect of sessions, $F(5, 200) = 26.52, p < .001$, but no effect of groups, $F(2, 40) = 0.72$. There was a significant Group \times Session interaction, $F(10, 200) = 5.63, p < .001$. Detailed comparisons showed

that whereas both normal and frontal animals displayed habituation from Session 1 to Session 4, $F(1, 13) = 37.66, p < .001$ and $F(1, 14) = 42.60, p < .001$, respectively, septal animals were not less active in Session 4 than in Session 1, $F(1, 13) = 0.01$. The lack of habituation in septal rats can be partly explained by their low levels of exploration in Session 1. This is suggested by the marginally significant correlation, $r(13) = .51, p < .10$, which was found between their individual activity levels in Session 1 and their individual rates of habituation (expressed as $S_1 - S_4/S_1$, where S_1 is activity in Session 1 and S_4 is activity in Session 4). Thus, the septal rats, which were more active in Session 1, were the more likely to habituate. Although there was a significant difference between septal rats and normal and frontal rats in Session 1, $F(1, 26) = 9.02, p < .01$ and $F(1, 27) = 6.25, p < .02$, respectively, this difference disappeared by Session 2, because of the marked decrease in exploratory activity of normal and frontal subjects. No significant difference between normal and frontal subjects was observed in any session.

In short, animals from the septal group were markedly impaired with respect to both their initial exploratory activity and their habituation pattern. No effect of lesion was found in the frontal group.

Reaction to the object displacement. Figure 3 clearly displays the fact that only normal animals renewed exploration during Session 5 and that no reaction was observed in either the septal group or the frontal group. The analysis of variance confirmed these impressions: A significant effect of the change

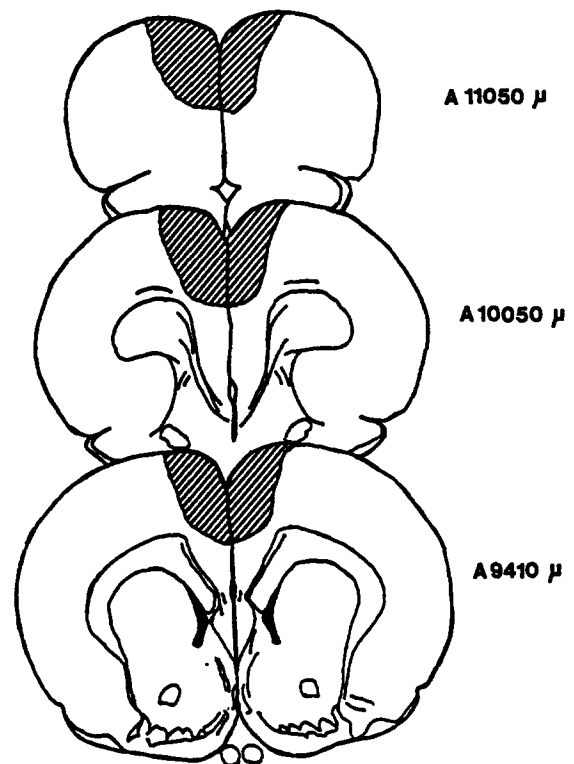


Figure 2. Schematic picture of a representative animal with a lesion of the medial frontal cortex.

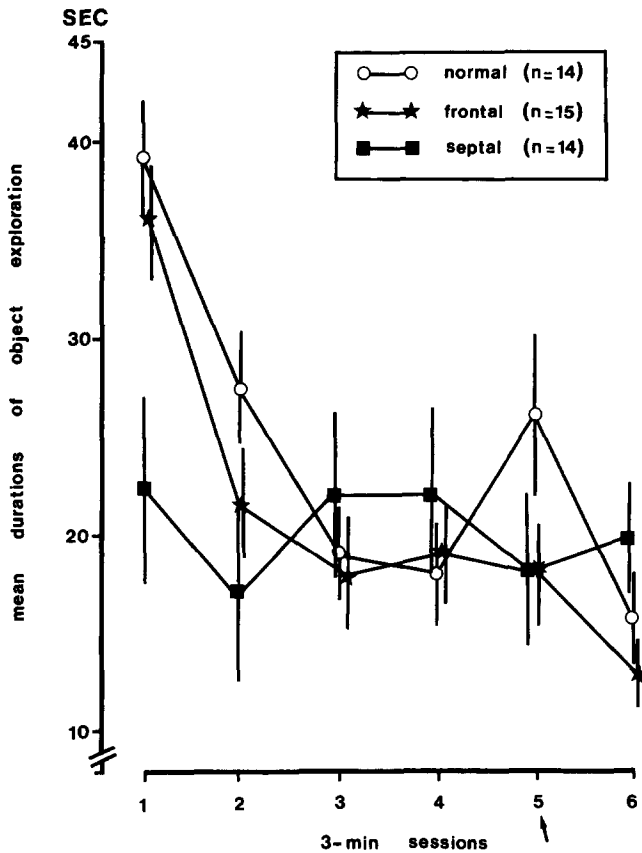


Figure 3. Mean (\pm SE) time spent investigating the objects for normal, frontal, and septal animals over six 3-min sessions (Experiment 1). (The arrow indicates the session during which one object was moved.)

was found in normal animals, $F(1, 13) = 5.45, p < .05$, but not in frontal, $F(1, 14) = 0.31$, or septal, $F(1, 13) = 2.37$, animals.

A more detailed analysis was undertaken, aimed at processing separately the displaced and nondisplaced objects during either the test session (after the change) or the reference session (before the change). Because there were no qualitative behavioral differences, in either group, between animals displaying a reaction in Session 6 (2 subjects per group) or those reacting during Session 5 (all remaining animals), the data from these two populations were pooled for subsequent analysis (Table 1).

The analysis of variance performed on this data showed a significant effect only for sessions, $F(1, 40) = 20.93, p < .001$, and significant Group \times Object, $F(2, 40) = 4.73, p < .02$, Group \times Session, $F(2, 40) = 7.37, p < .01$, and Object \times Session, $F(1, 40) = 11.06, p < .01$, interactions.

Detailed between-groups paired comparisons revealed that whereas normal animals did reinvestigate both the displaced object, $F(1, 13) = 7.58, p < .02$, and the nondisplaced ones, $F(1, 13) = 7.25, p < .02$, frontal subjects reexplored the displaced object, $F(1, 14) = 12.09, p < .01$, but not the

nondisplaced ones, $F(1, 14) = 1.91$. No significant reexploration of either class of objects was evident in the septal group.

Additional analyses of exploratory behaviors displayed during the test session (right-hand columns of Table 1) confirmed that frontal subjects investigated the displaced object more than the nondisplaced ones, $F(1, 14) = 7.35, p < .02$. This difference just missed significance in normal subjects, $F(1, 13) = 4.01, p < .10$. Last, no relation could be found in either group between the individual change-induced exploratory reactions and the individual rates of habituation.

Discussion

This experiment showed that normal rats reacted to a spatial change by reexploring the whole set of objects, although they reexplored more the displaced object than the nondisplaced ones. In contrast, frontal rats, although showing a normal pattern of habituation, were not observed reexploring all objects during the test session. Rather, they focalized most of their exploratory activity on the displaced object but did not renew exploration of the nondisplaced objects. Although the meaning of this result is not entirely clear, it suggests, at least, that the spatial knowledge acquired by frontal animals during the habituation sessions was accurate enough to allow them to detect a small change in the topographical organization of the objects. It should be pointed out that the present data are not consistent with the prevailing notion that the frontal cortex is involved in habituation (Kolb, 1974) and/or spatial mapping (Sutherland et al., 1982). Yet, from a number of experiments it has been documented that frontal cortex damaged animals are impaired in tasks requiring the

Table 1
Mean Change-Induced Reexploration and Mean Exploratory Activity During Test Session (Experiment 1)

Group	n	Mean change-induced reexploration			Exploratory activity during test session	
		All objects	Displaced object	Non-displaced objects	Displaced object	Non-displaced objects
Normal	14					
	<i>M</i>	+11.24***	+5.87*	+1.81*	9.99	5.75
	<i>SE</i>	2.38	2.15	0.67	2.21	0.74
Frontal	15					
	<i>M</i>	+0.50	+3.38**	-0.97	7.12†	3.79
	<i>SE</i>	1.89	0.97	0.70	1.20	0.61
Septal	14					
	<i>M</i>	+0.26	+0.78	-0.17	3.82	5.17
	<i>SE</i>	1.71	0.45	0.46	1.08	1.02

Note. Left-hand columns show the average differences in exploratory durations between the test session and the reference session. A positive score means renewed exploration during the test session (all values are in seconds). * $p < .02$. ** $p < .01$. *** $p < .001$. † $p < .02$, compared with nondisplaced objects.

use of maplike information in goal-oriented behavior (review in Kolb, 1984). Because the present task did not explicitly require the animal to engage in goal-oriented behavior, it may be that frontal animals are specifically impaired in using spatial information only when they have to orient to a particular goal.

Septal animals were dramatically impaired in all aspects of the exploratory process. They failed to show any habituation partly because of an initially lower level of exploration relative to normal and frontal animals, and they did not react to the change. These results are consistent with the well-documented deficit shown by septal animals in exploration and habituation (see review in Gray & McNaughton, 1983). However, the failure of septal rats to habituate precludes any strong conclusion about their ability to detect and react to a spatial change. It may suggest that they had not yet processed all the information as to the situation and, in particular, as to the location of the objects. Experiment 2 was an attempt to examine this possibility by providing septal animals more opportunity to habituate.

Experiment 2

Septal rats are known to be more reactive to stimulation and more emotional than normal rats (Gray & McNaughton, 1983). Thus, they may have failed to habituate in Experiment 1 because of the procedure which involved repeated manipulations. Consequently, Experiment 2 was undertaken with the aim of both giving septal animals a more extensive exploratory experience before the change and decreasing the amount of time the animals were manipulated. It was assumed that under these conditions septal rats would have more opportunity to habituate and therefore would be more prone to react to the change.

Method

Subjects

Twelve naive male Long-Evans rats, approximately 120 days of age and weighing 300–360 g, were used as subjects. Housing and feeding conditions were as in Experiment 1. Animals were randomly assigned to an unoperated control group ($n = 6$) or to a septal lesion group ($n = 6$).

Apparatus and Procedures

The apparatus and surgical and histological procedures were as in Experiment 1. Because the animals were naive, they were given an extensive period of handling both pre- and postoperatively. On the whole, they received 15 days of daily 10-min handling sessions before the start of the study. Animals were tested approximately 15–20 days after surgery. The behavioral procedures were generally as in Experiment 1 with a few notable exceptions. The animals were given a longer preliminary exploratory period (15 min as opposed to 3 min). Also, instead of six 3-min sessions given in a single day, each animal received six 15-min sessions distributed over 3 successive days (two sessions a day). The average between-sessions interval was 8–14 hr. Half of the animals in each group were tested in the morning; the other half were tested in the afternoon. Moving the object was made on the sixth session (as opposed to the fifth in Experiment 1).

Otherwise, all behavioral procedures were identical to those used in Experiment 1.

Data Collection and Analysis

Data collection was analogous to that in Experiment 1. In order to get a measure of within-sessions as well as between-sessions habituation, each session was broken into three successive 5-min periods. A VAR 3 analysis of variance (Rouanet & Lépine, 1970) was performed on the duration and number of contacts. Surgical treatment was the between measure, and 5-min periods and sessions were the repeated within measures. Another, more restricted VAR 3 analysis was made which separately processed displaced and nondisplaced objects in Session 5 (as the reference session) and Session 6 (as the test session). Again, for the latter analysis, each session was divided into three successive 5-min intervals.

Results

Anatomical Findings

The locus and extent of the lesions were similar to those described in Experiment 1. Therefore, all animals were considered to have acceptable damage to the septal area.

Behavioral Findings

Overall exploration and habituation. Figure 4 shows the mean time spent investigating the objects over successive sessions (upper panel: between-sessions time course) and over successive 5-min periods with all sessions combined (lower panel: within-sessions time course). The analysis of variance did not reveal any difference in the overall amount of exploration by each group, $F(1, 10) = 0.92$. There were significant effects for session, $F(5, 50) = 4.20$, $p < .01$, and period, $F(2, 20) = 9.62$, $p < .01$, and a significant Group \times Period interaction, $F(2, 20) = 6.09$, $p < .01$. Whereas normal animals displayed both between- and within-sessions habituation, respectively, $F(5, 25) = 5.19$, $p < .01$ and $F(2, 10) = 13.69$, $p < .01$, septal subjects failed to show any significant decrease in exploratory behavior both between and within sessions (both $F_s < 1$).

Reaction to the object displacement. An inspection of the exploratory behavior displayed by normal and septal animals during Sessions 5 (before the change) and 6 (after the change) failed to reveal significant change-induced reinvestigation in Session 6, although a nonsignificant tendency to increase exploration was present in normal animals, $F(1, 5) = 3.86$. However, because the marked habituation pattern exhibited by normal subjects within each session may have masked any significant change-induced reaction on Session 6, an examination of the first 5-min period of each session was undertaken. This analysis showed a progressive decrease in exploration from Session 1 through Session 5, followed by a significant increase in Session 6 of normal subjects only, $F(1, 5) = 11.53$, $p < .02$ (see Table 2). This overall increase was the result of a diffuse exploratory activity toward both displaced and nondisplaced objects, each of them not being significantly more explored than in Session 5. In contrast, septal animals did not show any significant change-induced reaction.

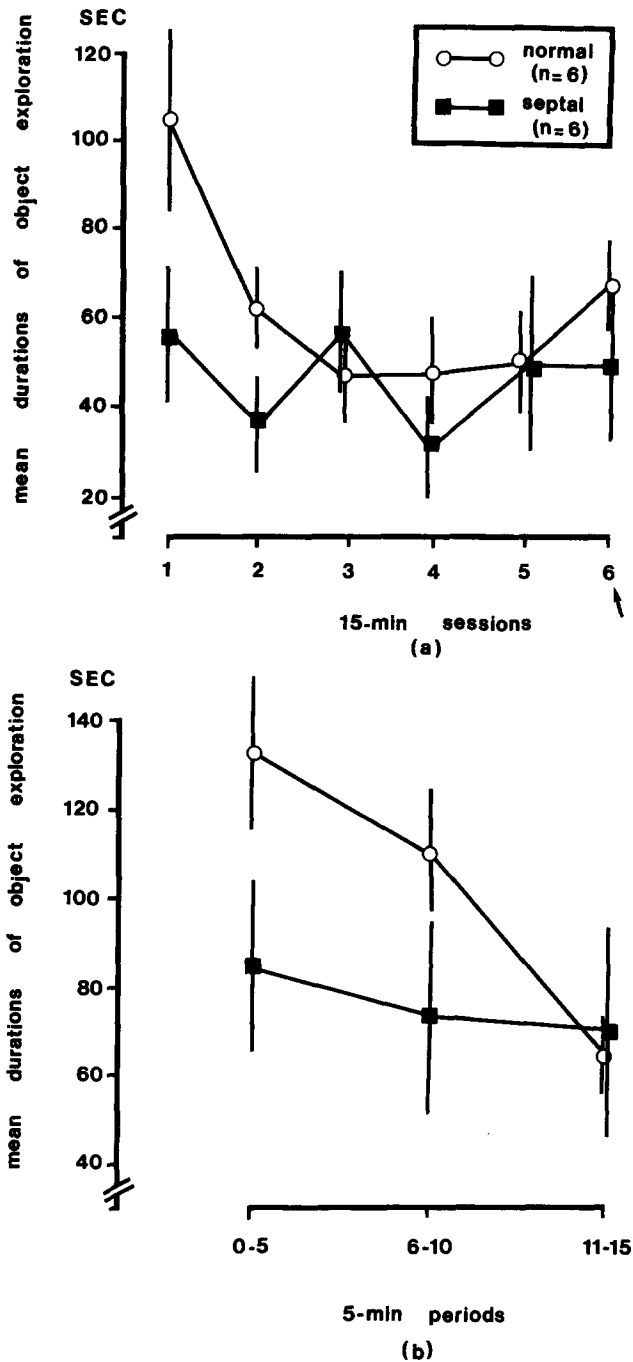


Figure 4. Mean (\pm SE) time spent investigating the objects for normal and septal animals (Experiment 2) over six 15-min sessions (upper panel) and over successive 5-min periods with all sessions blocked (lower panel). (The arrow in the upper panel shows the session during which one object was moved.)

Discussion

Giving septal animals a more extensive exploratory experience had no effect on their ability to react to the spatial change and to decrease activity within and between sessions. Therefore, their failure to display habituation between suc-

cessive sessions in Experiment 1 cannot be accounted for by repeated handling. These results are consistent with those showing deficits in habituation following total septal damage (but not following selective septal lesions; Kohler & Srebro, 1980), with a variety of measures such as the number of table entrances in the Maier three-table task (Ellen & Weston, 1983; Herrmann, Poucet, & Ellen, 1985a; Poucet & Herrmann, 1987) and the number (Capobianco, MacDougall, & Foster, 1977) or duration of exploratory head-poking responses (Feigley & Hamilton, 1971).

General Discussion

The present study yielded a clear dissociation as to the effects of medial frontal cortex or septal lesions regarding habituation of object exploration and reaction to a spatial change. Relative to normal unoperated animals, frontal rats were impaired only in their response-to-change behavior which was characterized by reexploration of the displaced object to the detriment of the nondisplaced ones. As a result, frontal animals did not display an overall renewal of exploration of the whole set of objects during the test session. In contrast, septal subjects were impaired in both habituation and response-to-change behavior. In particular, no evidence was provided that they had detected the change.

Because the current hypotheses about the septo-hippocampal system function are linked to its role in cognitive mapping, that is, in acquisition and use of spatial representations of the environment, such impairments following septal damage were not unexpected. As a matter of fact, reacting to a spatial change requires that some kind of representation of the former situation be built up so that comparing that representation with the actual arrangement can be achieved. As other investigators have suggested (Ellen & Weston, 1983; O'Keefe & Nadel, 1978), the habituation pattern could reflect the time course of the process of acquiring spatial (and non-spatial) information. Accordingly, as septal animals do not habituate, they could be specifically impaired in acquiring the relevant spatial information. However, the reason for the septal deficit in habituation is not entirely clear. Evidence from Experiment 1 suggests that this deficit could derive

Table 2
Mean Change-Induced Reexploration Over the First 5-min Period of Sessions 5 and 6 (Experiment 2)

Group	n	All objects	Displaced object	Nondisplaced objects
Normal	6			
		M	+7.87*	+1.29
		SE	2.31	1.69
				+2.19
				0.88
Septal	6			
		M	+4.73	-2.41
		SE	3.95	1.28
				+2.38
				1.09

Note. All values are in seconds. A positive score means increased exploration during the test session (Session 6) with respect to the reference session (Session 5).

* $p < .02$.

merely from a lack of initial engagement in object exploration, perhaps due to a greater level of emotionality. In contrast, the results of Experiment 2 support the idea that the habituation deficit in septal rats is rather the consequence of impaired cognitive processing at a more general level because even when given more time to habituate, the animals were still impaired on this measure. Thus, these results are inconclusive with respect to the basis of the habituation deficit in septal rats. Further studies should help to clarify this issue.

Clearly, such hypotheses cannot apply to medial frontal cortex damaged animals. These animals displayed a behavioral pattern similar to that of normal animals with the exception of a specific impairment in renewed exploration of the objects following the change, resulting from a lack of interest toward the nondisplaced objects. Although it may be casual, this result deserves further mention, especially in view of recent theories that have emphasized the role of frontal cortex in planning and attentional processes (Fuster, 1980; Kolb, 1984; Milner, Petrides, & Smith, 1985). In a recent study, some evidence was provided that the frontal system is critical in paying attention to two stimuli simultaneously (Olton, Wenk, Church, & Meck, 1988). In some respect, frontal animals would be impaired in "divided attention." Although such a hypothesis fits well with the apparent neglect displayed by frontal animals to the nondisplaced objects during the test session of Experiment 1, it does not fully account for their accurate knowledge about the spatial locations of objects. Indeed, such knowledge requires simultaneous processing of spatial information in order that a coherent model of the topographical organization of space is built up. Thus, although a frontal cortex function in attentional systems involved in tasks requiring high levels of cognitive processing is likely, clearly more research is needed to clarify the exact role of this structure in those tasks.

Although lesions of the septal area and the medial frontal cortex have similar deleterious effects in most goal-oriented tasks, it has been recently shown that with repeated testing, damaged animals are able to improve performance and finally learn the correct orientation toward a single goal location (Poucet & Herrmann, 1987). Because both structures are hypothesized to have distinct functions in cognitive mapping, it can be suggested that the initial deficits may be overcome through distinct mechanisms. Septal animals could improve through the use of emphasized specific spatial relations, a strategy that still does not imply the acquisition and use of a spatial representation. In contrast, frontal animals could rely on a remaining ability to encode spatial information in a piecemeal fashion, over temporally distinct episodes (for a previous demonstration of this type of processing in normal animals, see Ellen, Sotteres, & Wages, 1984). However, as it has been demonstrated that frontal animals have difficulty in processing temporal information (Kesner & Holbrook, 1987), such piecemeal acquisition of spatial information would not necessarily provide the animals with information about the temporal context of each episode. Obviously, these hypotheses are highly speculative. However, the fact that completely distinct patterns of behaviors were observed in the present exploration study raises the question as to which spatial function is selectively abolished following each par-

ticular lesion and therefore what can be the mechanisms used to overcome the spatial deficits associated with each lesion.

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Call for Nominations

The Publications and Communications Board has opened nominations for the editorships of the *Journal of Experimental Psychology: Animal Behavior Processes*, *Contemporary Psychology*, the Personality Processes and Individual Differences section of the *Journal of Personality and Social Psychology*, *Psychological Assessment: A Journal of Consulting and Clinical Psychology*, and *Psychology and Aging* for the years 1992-1997. Michael Domjan, Ellen Berscheid, Irwin Sarason, Alan Kazdin, and M. Powell Lawton, respectively, are the incumbent editors. Candidates must be members of APA and should be available to start receiving manuscripts in early 1991 to prepare for issues published in 1992. Please note that the P&C Board encourages more participation by members of underrepresented groups in the publication process and would particularly welcome such nominees. To nominate candidates, prepare a statement of one page or less in support of each candidate.

- For *JEP: Animal*, submit nominations to Bruce Overmier, Department of Psychology-Elliott Hall, University of Minnesota, 75 East River Road, Minneapolis, Minnesota 55455. Other members of the search committee are Donald A. Riley, Sara J. Shettleworth, Allan R. Wagner, and John L. Williams.
- For *Contemporary Psychology*, submit nominations to Don Foss, Department of Psychology, University of Texas, Austin, Texas 78712. Other members of the search committee are Edward E. Jones, Gardner Lindzey, Anne Pick, and Hans Strupp.
- For *JPSP: Personality*, submit nominations to Arthur Bodin, Mental Research Institute, 555 Middlefield Road, Palo Alto, California 94301. Other members of the search committee are Charles S. Carver, Ravenna S. Helson, Walter Mischel, Lawrence A. Pervin, and Jerry S. Wiggins.
- For *Psychological Assessment*, submit nominations to Richard Mayer, Department of Psychology, University of California-Santa Barbara, Santa Barbara, California 93106. Other members of the search committee are David H. Barlow and Ruth G. Matarazzo.
- For *Psychology and Aging*, submit nominations to Martha Storandt, Department of Psychology, Washington University, St. Louis, Missouri 63130. Other members of the search committee are David Arenberg and Ilene C. Siegler.

First review of nominations will begin January 15, 1990.