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Authors

Wallace, Richard J.
Barnett, S.A.

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AVOIDANCE OF NEW OBJECTS BY THE BLACK RAT, *RATTUS RATTUS*, AFTER OBJECT PRESENTATION AND CHANGE

Richard J. Wallace
S.A. Barnett
Australian National University

ABSTRACT: This work compares object replacement and object presentation as causes of avoidance (new object reaction or neophobia). The movements of wild black rats, *Rattus rattus*, living in an automated plus maze were recorded (1) after replacing a familiar object (in a familiar place) with a series of novel objects, (2) after presenting a novel object in a familiar place where there had been no object. Replacing one object by another did not delay entry to the maze arm containing it. In contrast, the presence of a new object in a previously empty arm did increase the latency of the first approach (new object reaction), although after the first entry, the rate of visiting the arms and the time spent in them, which are measures of subsequent approach, were unaffected. Hence, this form of neophobic behavior was evoked only by the presence of a new object where none had been before. Differences with earlier reports can be resolved in most cases when attention is paid to the difference between presentation and replacement.

When an object such as an iron strip or a block of wood is placed in the foraging area of wild rats (*Rattus*) of a commensal species, the rats usually avoid it. (On *Rattus norvegicus*, see Barnett, 1958; Calhoun, 1962; Chitty & Shorten, 1946; Shorten, 1954; on *Rattus rattus*, Cowen, 1976; Cowan & Barnett, 1975.) Chitty and his coworkers called this behavior "new object reaction" (Chitty & Kempson, 1949; Shorten, 1954). Later it was named "neophobia" (Barnett, 1958), with the same reference to maintaining a distance from a location of change.

This behavior should be distinguished from "flavor neophobia," that is, eating or drinking less than expected when a novel mixture is offered (Carroll, Dinc, Levy & Smith, 1975; Domjan & Gillan, 1976; Miller & Holzman, 1981). In studies of flavor neophobia, subjects are usually described as consuming appreciable amounts of food; hence the "neophobia" does not prevent the animals from making and maintaining contact with the source of novelty. The assumption that this behavior is equivalent to avoidance of new objects by commensal rats

Address correspondence to Richard J. Wallace, Department of Computer Science, Kingsbury Hall, University of New Hampshire, Durham, NH 03824.

may have arisen from the use, in some experiments, of reduced food intake as a measure of locomotor avoidance when a new object is placed near the food supply (Barnett, 1958; Shorten, 1954; for further discussion see Barnett, 1988). The focus in the present paper is on locomotor avoidance of objects. For clarity in the account that follows, the original name, new object reaction, is used.

New object reaction occurs only in a familiar region. For example, in experiments by Cowan (1976), avoidance by *R. rattus* was observed only when a new object was placed in an environment previously visited by the rats; the presence of the same object in a newly accessible region did not interfere with exploration (see also Calhoun, 1962, on *R. norvegicus*). Transferring an object from one place to another, in a familiar environment, can also lead to avoidance by rats of both species (Cowan, 1976; Shorten, 1954). In contrast, removal of an object from a familiar environment has no effect on *R. norvegicus* (Shorten, 1954).

In the experiments just described, the method was always object presentation (or removal). An alternative is object replacement, that is, substituting a new object for a familiar one in the same place. This too has been said to cause avoidance by both *R. norvegicus* and *R. rattus* (Advani & Idris, 1982; Cowan, 1976; Galef, 1970; Mitchell, 1976; Shorten, 1954). But Galef (1970) and Mitchell (1976) used food consumption as their behavioral index, and both reported relatively short delays before feeding; and, of the three tests mentioned by Shorten (1954) which seem to have involved replacement (see pp. 311, 318, 319), only one led to noticeable avoidance. In related work, olfactory changes caused by applying unfamiliar substances to an object, such as a food container, or by washing it, had no effect (Cowan, 1976; Shorten, 1954). Together, these experiments suggest that avoidance is more reliably evoked by adding new entities than by altering existing ones.

The present work gives further evidence on the different effects of object presentation and object replacement on new object reaction. As in earlier studies from this laboratory, locomotion into an area was recorded directly. In addition, novel objects were in places separated from those where food and water were found, so that new object reaction could be observed independently of eating and drinking.

METHOD

Animals

Eight male and eight female *Rattus rattus* were used for Experiment 1 on object replacement. Eight males were used for Experiment

2 on object presentation; one group was sufficient in this case, to determine whether any aspect of the experimental situation precluded the usual new object reaction. The animals were trapped in the roof of a building at the Australian National University. Their age at trapping was estimated at 30-50 days. Isolation is tolerated well by this species. Before the experiment, therefore, until they were about one year old, they were housed individually in wire cages (36 x 30 x 25 cm), with water and food (Mecon Rat and Mouse Cubes from Fidelity Feeds, Murrumburrah, N.S.W) always available. During the experiments, all animals fed well: daily group means for food removed from the hopper were 19 to 26 g.

Apparatus

While under experiment, each rat lived alone in one of four plus mazes (Figure 1; *cf.* Barnett & Cowan, 1976). Two adjacent arms contained, respectively, a basket of food and a water bottle, each at the end of the arm. The floor of the food arm was covered with sawdust. The other two arms contained the objects used in the experiments. Each maze was lit from above by a 40 W circular fluorescent tube. The central compartment and food arm had black plastic tops; the other arms were covered with clear Perspex. The mazes were in a sound-insulated room kept at 19-22°C, on a 12:12 light-dark cycle with darkfall at 1900 hours.

As in earlier research (Cowan & Barnett, 1975), a "visit" to an arm began when the photocell beam at the end of the arm was broken, and ended when the beam at the beginning of the tunnel leading to the arm was broken (Figure 1). These events were logged on a Digital PDP 8/e computer, with a precision of 0.01 min.

Each object used to test for new object reaction was fastened by a screw to a metal platform 1 cm high; the platform covered the floor of the arm beyond the tunnel (Figure 1). The screw hole in a platform was centered transversely in the arm and was 9.5 cm from the end of the tunnel, immediately in front of the distal photocell beam.

Fourteen kinds of object were used; each was 2 to 4 cm high and 1 to 4 cm wide (Figure 2). All objects were of metal or glass and so could not be gnawed apart. In the figure, objects not radially symmetrical are shown as they would appear from the tunnel of an arm.

Procedure

After a 24 h period ending at 1200 hrs, during which all arms were open and the first pair of objects were in place, rats were given daily trials lasting from 1800 (1 h before darkfall) until 2300 hrs. During each trial the food and water arms were closed, to avoid com-

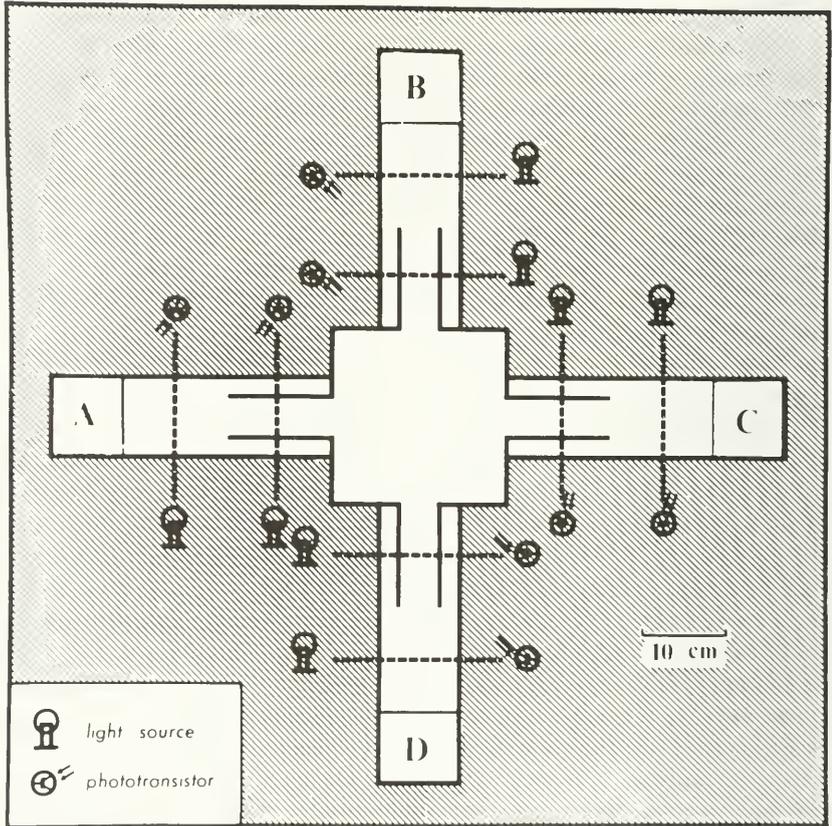


FIGURE 1. Schematic diagram of plus maze showing locations of photocell beams in each arm. A tunnel occupied the first 10 cm of each arm and was 7.5 cm wide, while the width of the open arm was 10.5 cm. Food and water were in the end compartments of arms A and B, respectively. Arms C and D were open during the trials.

peting responses that might affect locomotor activity in the experimental arms. After a trial, the experimental arms were closed and the food and water arms reopened. Objects in the arms were replaced on the day after each trial at about 1300 hrs. The used objects were cleaned for further use by washing with soap and water, thorough rinsing and immersion in 70% alcohol. Food was replenished at this time and water bottles were refilled.

In Experiment 1, on object replacement, the females were exposed to an object in each object arm for 8 preliminary trials. Owing to an oversight the males were similarly exposed for only 7 days. Either period is more than enough for measures of locomotor exploration to stabilize (Cowan & Barnett, 1975). During this condition, each

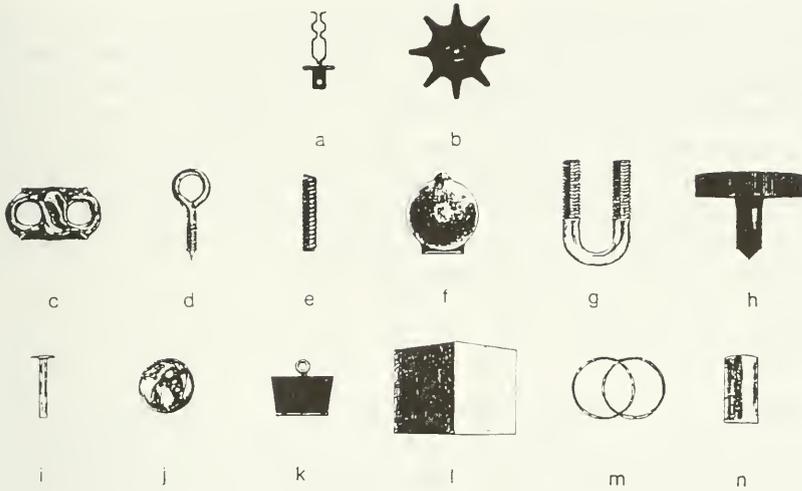


FIGURE 2. Objects placed in arms: a. Grille clip, b. Gear, c. Cable clamp grip, d. Screw eye, e. Spring, f. Disc, g. Cable clamp thread, h. Camera screw, i. Paper binder, j. Marble, k. Paper clip, l. Cube, m. Rings, n. Testtube cap. Objects in order presented to one rat in Exp. 1: a and b in preliminary condition, b replaced by c, d,..., n in experimental condition. For corresponding rat in Exp. 2, a and c appeared on Trial 8, c was replaced as above.

object was replaced daily by another of identical type, for example, a grille clip by another grille clip. Twelve experimental trials followed: in each, a new type of object was placed in one arm (changing or C-arm), while the object in the other arm (unchanging or U-arm) was replaced, as before, by another of the same type.

In Experiment 2, on object presentation, the preliminary condition lasted for 7 days, during which both object arms were empty. On Day 8, objects were put in both arms. On the next 11 trials a new type of object was put each day in the C-arm, while the object in the U-arm was replaced by another of the same type. Hence the procedure during the experimental trials was identical to that of Experiment 1.

For the preliminary condition in Experiment 1, four pairs of objects were chosen at random: grille clip and gear (Figure 2a,b), cable clamp grip and screw eye (c, d), spring and disc (e, f), cable clamp thread and camera screw (g, h). Each pair was used with the two rats run in the same maze, so that a given object appeared in the left arm for one rat and in the right arm for the other. In addition, the 12 kinds of object that were substituted in the C-arm were divided into groups of six (groups "A" and "B", respectively, shown in Figure 2; group A consisted of objects c through h and group B of objects i through n). All objects in one group were presented before objects in

the other; half the subjects were exposed first to group A objects, and half to group B. For each group of objects a single random order of presentation was derived: each rat was exposed to the objects in this order beginning at one of four points. For example, for one rat the order of the objects replacing object b was c, d, e, f, g, h, i, j, k, l, m, n; in another case, d was replaced by e, f, g, h, a, b, k, l, m, n, i, j. In this way the transitions between objects on successive trials were similar for all rats, although the new object presented on trial n was different for each subject in an experimental group.

Statistical Analysis

The measures of behavior in the maze were i) the latency, that is, the interval between the opening of an object arm and the first breaking of the distal beam, ii) the hourly visit rate to each arm, based on total visits and the duration of the trial after the first visit to that arm, iii) the mean visit duration, iv) the mean inter-visit interval (IVI). These measures were chosen instead of the number of visits and total visit duration used earlier (reviewed by Barnett & Cowan, 1976) because they meet the conditions of logical independence and generality more adequately.

Differences between groups and effects of experimental conditions were analyzed with repeated measures ANOVAs and Newman-Keuls tests. For this analysis, trials were grouped in blocks of four (or three for the second block of preliminary trials for males), and log-transformed values were used. In Experiment 2, missing data due to new object reaction precluded the use of ANOVAs except for latencies. Paired comparison t tests based on all rats in each experiment were used to evaluate differences between the last preliminary and first experimental trials. Trends across trials during each condition were analyzed with tests for linear regression and deviations from it. (The latter were never statistically significant and are not considered further.) Stability of differences between subjects in each experimental group was evaluated with Kendall's coefficient of concordance, W , for each measure across trial blocks.

RESULTS

During the preliminary trials of both experiments, the major trends were declines in latencies and visit rates for both arms (Table 1). For the most part, these took place over the first three trials, and tests in which Trials 1 and 2 were omitted showed no significant trends over the remaining days ($p > .10$). The latencies of the fe-

TABLE 1
Activity Means for First and Last Trials in Each Condition

Expt Sex	<i>Trial and Arm</i>							
	<i>First</i>		<i>Last</i>		<i>First</i>		<i>Last</i>	
	<i>Preliminary</i>		<i>Preliminary</i>		<i>Experiment</i>		<i>Experiment</i>	
	<i>U</i>	<i>C</i>	<i>U</i>	<i>C</i>	<i>U</i>	<i>C</i>	<i>U</i>	<i>C</i>
Latencies (min)								
1 f.	115.9	107.0	71.8	67.8	82.7	80.5	63.1	60.1
m.	39.7	47.4	18.7*	22.4	18.0	19.4	22.2	16.8
2 m.	35.5	71.5	11.6+	13.9*	159.3	104.5	104.0	122.2
Visit Rates (no./h)								
1 f.	11.9	8.6	6.1	3.4*	6.5	4.9	2.1+	2.6+
m.	9.6	15.0	3.1 [!]	3.6 [!]	3.4	4.0	2.6	3.0
2 m.	13.7	10.9	3.1 [!]	3.2 [!]	2.2	2.3	1.4	2.6
Visit Durations (min)								
1 f.	1.6	1.3	2.7	4.6	4.2	1.3	1.5	13.4
m.	1.1	1.4	9.0*	2.0	6.0	4.4	11.9	1.2
2 m.	2.6	1.9	3.3	5.2+	3.2	3.2	12.1	3.0
Inter-Visit Intervals (min)								
1 f.	3.1	3.5	5.8	5.2	5.3	6.0	18.8*	8.4
m.	2.2	3.9	3.5	6.0	4.5	4.6	5.2	6.0
2 m.	1.8	2.1	3.8	9.8*	8.9	17.1	11.8	4.9

U = U-arm, C = C-arm. Superscripts under last trial of each condition are results of trend tests for each arm in that condition. [!] $p < 0.01$, * $p < 0.05$, + $p < 0.10$.

males, however, varied markedly, and the trends for this group over the whole condition were not statistically significant (Table 1). Latencies for females were also greater than for males: for the U-arm, $F(1, 14) = 7.53$, $p < .025$; C-arm: $F(1, 14) = 5.48$, $p < .05$. Visit durations and IVIs of all groups also lengthened during this condition (Table 1). During the experimental trials there was evidence of a further decline in activity.

In Experiment 1, replacing objects in the C-arm had no evident effect on behavior (Table 1). In particular, for the comparison of latencies on the last preliminary and first experimental trials, $t(15) = .58$, $p > .25$ (one-tail). As a further test of avoidance, the proportion of trials on which the first choice was the C-arm was computed for each animal. For the females, the means for preliminary and experimental trials were 0.44 and 0.41, respectively, and the mean for the last six experimental trials was 0.44. For the males, the corresponding fig-

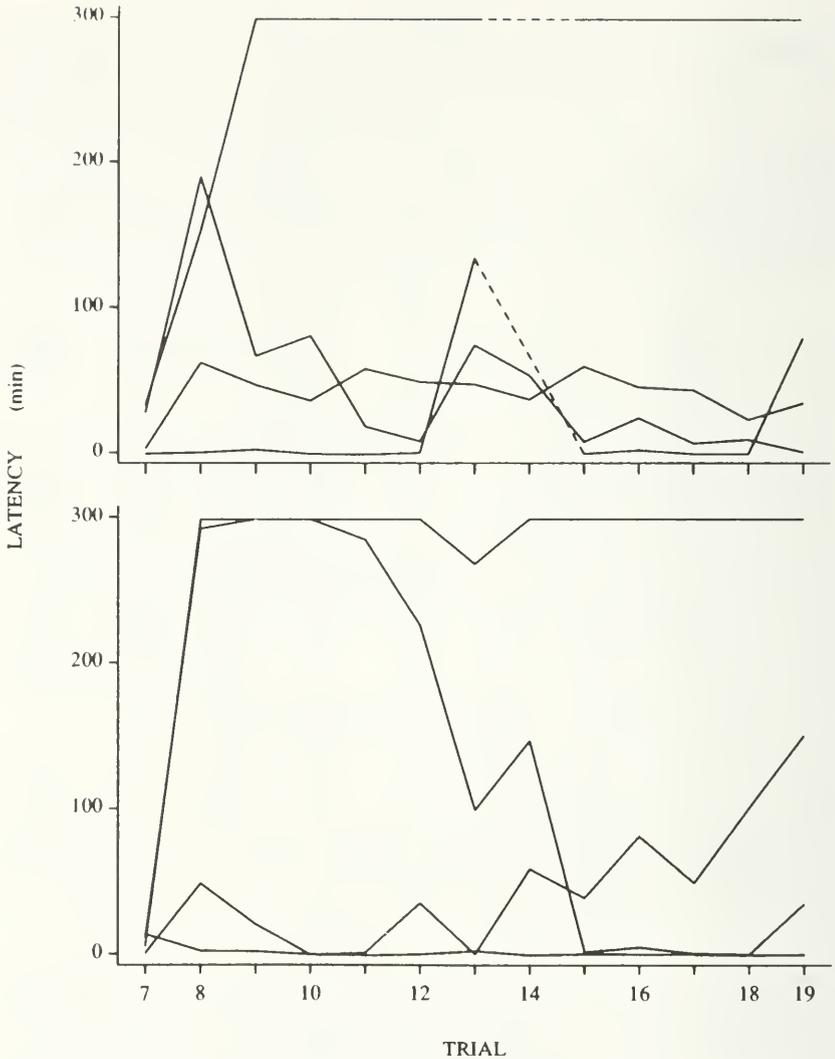


FIGURE 3. Latencies to enter arms, for individual rats in Experiment 2 (means of U- and C-arms on each trial). For clarity, data are shown in two panels. Dashed lines indicate lost data for two rats on Trial 14. U-arm (top); C-arm (bottom).

ures were 0.38, 0.39, and 0.38. This measure, therefore, also gave no evidence of avoidance of the C-arm during the experimental trials.

In Experiment 2, as expected, the first appearance of objects in the arms increased the latency of most rats (Table 1, Figure 3). Both comparisons between the last preliminary and first experimental trials were statistically significant (U-arm: $t(7) = 3.05, p < .01$; C-arm:

$t(7) = 2.03, p < .05$ (one-tail)), and corresponding results were given by the ANOVAs. In addition, a combined analysis of latencies for the male groups of both experiments yielded statistically significant effects for Groups \times Trial-Blocks (U-arm: $F(4, 56) = 3.57, p < .025$; C-arm: $F(4, 56) = 3.30, p < .025$), but not for either factor alone. Other behavioral measures were unaffected ($p > .10$).

The absence of differences in the behavioral measures, apart from latency, does not preclude temporary effects. In particular, visits might be shorter and more frequent while the animal is habituating to the new object. Examination of times and durations of initial visits on the last preliminary and early experimental trials showed no obvious changes. When mean durations of the first five (10) visits on the last preliminary trial were compared with those of the first five (10) visits after object presentation, no statistically significant effects emerged, ($p > .05$). The absence of behavioral effects after the first arm entry is the more notable in view of the stability of individual differences in all measures in both experiments, as shown by Kendall's W (in most instances, $p < .025$).

DISCUSSION

The measures of latency and visit rate during the preliminary trials yield evidence on new place reaction at variance with other accounts. Latency, a measure of avoidance, declined steeply during this condition. But visit rate, a measure of approach, also declined, especially between Trials 1 and 2. The latter finding accords with the results of earlier work on several species (Chopra & Sood, 1984; Cowan, 1976, 1977; Cowan & Barnett, 1975) in which the neophilic effect of new locations has been emphasized. The changes in latency, however, suggest a brief initial avoidance of such places. This effect may have been due, in part, to habituation to the disturbance at the beginning of each trial, but it is consistent with findings on domestic Norway rats (reviewed by Wallace, 1988).

In Experiment 2, as expected, the first appearance of an object resulted in avoidance of the arm containing it. This was shown by the latency of the first visit to the arm within the daily trial, an effect that sometimes persisted unabated for the entire 12 day period. The wide range of scores on this measure corresponds to earlier findings (Barnett, 1958; Cowan, 1976).

The importance of recording latency is illustrated by the fact that, in the present experiments, it was the only measure to show an effect of presenting a new object. Rats that entered the arms, whatever their latency, visited each arm at about the same rate as before and remained in the arms for similar durations. Individual differ-

ences were also stable. These results clarify previous findings with the plus maze, that showed effects of new objects on entrance latency, number of visits and time spent in the experimental arm (Cowan, 1976, 1977; Cowan & Barnett, 1975); it now appears that the latter effects are secondary to the longer latencies. At the same time, the present results are consistent with those of earlier experiments on domestic *R. norvegicus* (Barnett, Smart & Widdowson, 1971) and *R. rattus* (Cowan & Barnett, 1975), in which duration of activity outside the nest was maintained in the face of environmental alterations.

In contrast to the sudden appearance of an object, drastic changes in the shape and minor changes in the size of an object had no discernible effect on any measure of movement. Yet observations on the sensory abilities of *R. norvegicus* suggest that our rats (though of a different species) would have detected the change of objects both visually and tactually. (1) Experiments on visual discrimination have shown the distinctiveness and equivalence of different patterns to be remarkably similar for rats and human beings (Lashley, 1938). Findings on visual acuity also indicate that differences such as those between the objects (Figure 2) are well within their powers of discrimination (Birch & Jacobs, 1979). (2) Since each object partly blocked the arm, the rat had to touch it to break the distal photocell beam and record a visit; hence, there was also tactile input. In similar conditions, domestic rats respond to object replacement within seconds of encounter, by grasping and manipulating the object (Wallace, 1978) or by prolonged investigation (Berlyne, 1950; Blanchard, Shelton & Blanchard, 1970). Also relevant are observations by Shorten (1954) and by Southern, Watson & Chitty (1946) of new object reaction after presentation, which evidently depended on tactile cues.

The behavior of our rats after object replacement and object presentation shows that they perceived the two situations differently. Two explanations are tenable. (1) Rats may respond to the amount of novelty, that is, both to the magnitude of change in a single property and to the number of altered features. If so, avoidance would occur when a threshold value is exceeded, and this must have happened in Experiment 2 but not in Experiment 1 (*cf.* Berlyne (1960) on the behavioral effects of "collative variables"). (2) Alternatively, they may display avoidance only after a change in the object-in-location relationship, and not to changes in the attributes of an object. If object replacement in Experiment 1 was perceived as alteration of an object already in that location, there would then be no avoidance. This hypothesis is implied in the definition which restricts the term neophobia to "the avoidance of unfamiliar objects in a familiar environment" (Barnett, 1981).

Some laboratory studies, in which avoidance by *R. norvegicus* has been attributed to object replacement, seem in conflict with the results of Experiment 1, but these experiments combine both presenta-

tion and replacement (Braveman, 1978; Galef, 1970; Mitchell, 1976). The rats had access to food or water for a short period daily, and object replacement consisted of changing the food or water container; but this was put in a place where, for almost 24 h, there had been no object at all. Shorten (1954) observed avoidance when an object was removed and replaced after only 1 h. Braveman (1978) and Galef (1970) also put the new container in a different place for the test trial: their method is therefore properly described as object presentation after object removal. In addition, in each of these studies, approach was measured indirectly, by food consumed or latency to feed; hence, effects on feeding were not distinguished from changes in locomotor approach. No conclusions can be drawn regarding Shorten's (1954) field observation of avoidance after replacement, since the description of methods is incomplete.

Studies on *R. rattus*, by Cowan (1976, 1983) and Advani & Idris (1982), seem to give valid evidence of avoidance due to object replacement. But, in both, the index of avoidance is a decline in food consumption. (In related experiments by Mitchell, Kirschbaum & Perry, 1975 and by Mitchell, 1976, when *R. norvegicus* were presented with a novel container and a familiar one, at first they fed almost exclusively from the latter). Perhaps object change can suppress feeding without affecting movement toward the changed object. We need to know much more about the relationship between feeding behavior and new object reaction.

With reference to the behavior of wild rats of commensal species, Barnett (1981) wrote: "The question of what is, for a rat, a 'new object' has yet to be fully answered." The studies cited above and in the introduction, together with our present findings, take the analysis of new object reaction and related phenomena some way further: (1) The response of wild rats to a *new place* is mainly neophilic, but may include a brief neophobic component. (2) "Flavor neophobia" should be distinguished from the response to new objects; how it is related to new object reaction is still unclear. (3) Substituting one object for another, in a familiar place, has little or no effect on movements. (4) Putting a strange object in a familiar place, where none had been before, is likely to induce prolonged avoidance of that place, but only by rats of commensal species (*cf.* Bammer, Barnett & Marples, 1988). The last finding conforms with the suggestion that new object reaction is due to natural selection in environments where rats are subject to vigorous human predation.

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