

The role of exploratory experience in a shortcut task by golden hamsters (*Mesocricetus auratus*)

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The aim of this experiment was to examine the role of exploratory experience on the ability to take a shortcut. In the first phase, two subspaces, X and Y, each consisting of two baited tables related by a runway, were separately explored by hamsters. In the second phase, the experimental group explored a connecting pathway between X and Y. The animals were finally submitted to a shortcut test during 2 days: in this test, in order to go from X to Y, they could choose between the longer familiar pathway and two shorter new pathways. In comparison with a control group, which did not undergo the second phase, the experimental group displayed a significant preference for the shortcut that did not cross the linking path with which they had had experience or either of the two distant portions whose linkage the animals had experienced. These results suggest that, in this simple situation, additional experience of a linking element between two separated subspaces has a beneficial effect on the setting up of spatial relationships between them, and perhaps on the representation of the whole situation.

Spatial problem-solving, shortcut, and detour tasks have been widely used to test the cognitive abilities of several species of mammals (e.g., rats—Maier, 1929, 1932; Tolman & Honzik, 1930; Tolman, Ritchie, & Kalish, 1946; Stahl & Ellen, 1974; hamsters—Chapuis & Lavergne, 1980; monkeys—Kohler, 1925; Menzel, 1973; cats—Poucet, Thinus-Blanc, & Chapuis, 1983; dogs—Chapuis, Thinus-Blanc, & Poucet, 1983; Chapuis & Varlet, 1987). The animals' success in these tasks appears to be highly related to a sudden understanding of some relationship between different elements of the problem. This "insight" can be defined as a reorganization of previously processed information, leading to an original solution (for example, the use of a path never experienced before). Thus, the preliminary investigatory phase during which information is gathered is crucial. Using a classical spatial problem-solving task (Maier's three-table task), Ellen, Parko, Wages, Doherty, and Herrmann (1982), Herrmann, Bahr, Bremmer, and Ellen (1982), and Stahl and Ellen (1974) have shown in rats that exploration is indeed a necessary factor in the achievement of a solution. More generally, exploratory behavior appears to be basic to the setting up of spatial relationships. According to Tolman (1948) and O'Keefe and Nadel (1978), the function of exploratory activity is to constitute new cognitive maps or to update existing maps. This updating function of exploration has been very simply demonstrated in gerbils (Cheal, 1978; Wilz & Bolton, 1971) and in hamsters (Poucet, Durup, Chapuis, & Thinus-Blanc, 1986; Thinus-Blanc, in press). After habituation of exploration in an open field containing objects, the rearrangement of familiar objects elicits

a renewal of exploration; in some cases, this exploration is as thorough as if the situation were novel.

In the present experiment we investigated, in hamsters, the role of exploratory experience in the combination of two previously separated subspaces, X and Y. In the first phase, X and Y were independently run. In the second phase, the hamsters were allowed to investigate a connecting runway between X and Y. This phase was followed by a shortcut test, in which new runways (leading more directly to the goal) were available to the hamsters. We wanted to determine whether the exploration of the connecting runway elicited the "coalescence" of the two subspaces, either place in X [and Y] being related to either place in Y [and X] by the shorter path. If this coalescence did not occur, the animals should use the familiar runway, even though it was longer, to go between X and Y. In other words, we asked whether exploration allowed the constitution and use of a map, characterized by plasticity in terms of choice of equivalent pathways, or whether the hamsters' behavior was dependent on the previously experienced route linking the two subspaces. If the latter were the case, it would mean that X and Y still represented two separate clusters.

It should be emphasized that we use the term *exploration* in a wide sense. It was, in fact, a *controlled exploration*, since the animals' movements were restricted by pathways. They were also oriented (from a starting table to a goal). Nevertheless, the animals were free to move in either direction on the pathway and they did display exploratory activity.

METHOD

Forty-six naive golden hamsters (*Mesocricetus auratus*), 14 females and 32 males, approximately 3½ months old at the start of the experiment, served as subjects. They had food available ad lib in their cages.

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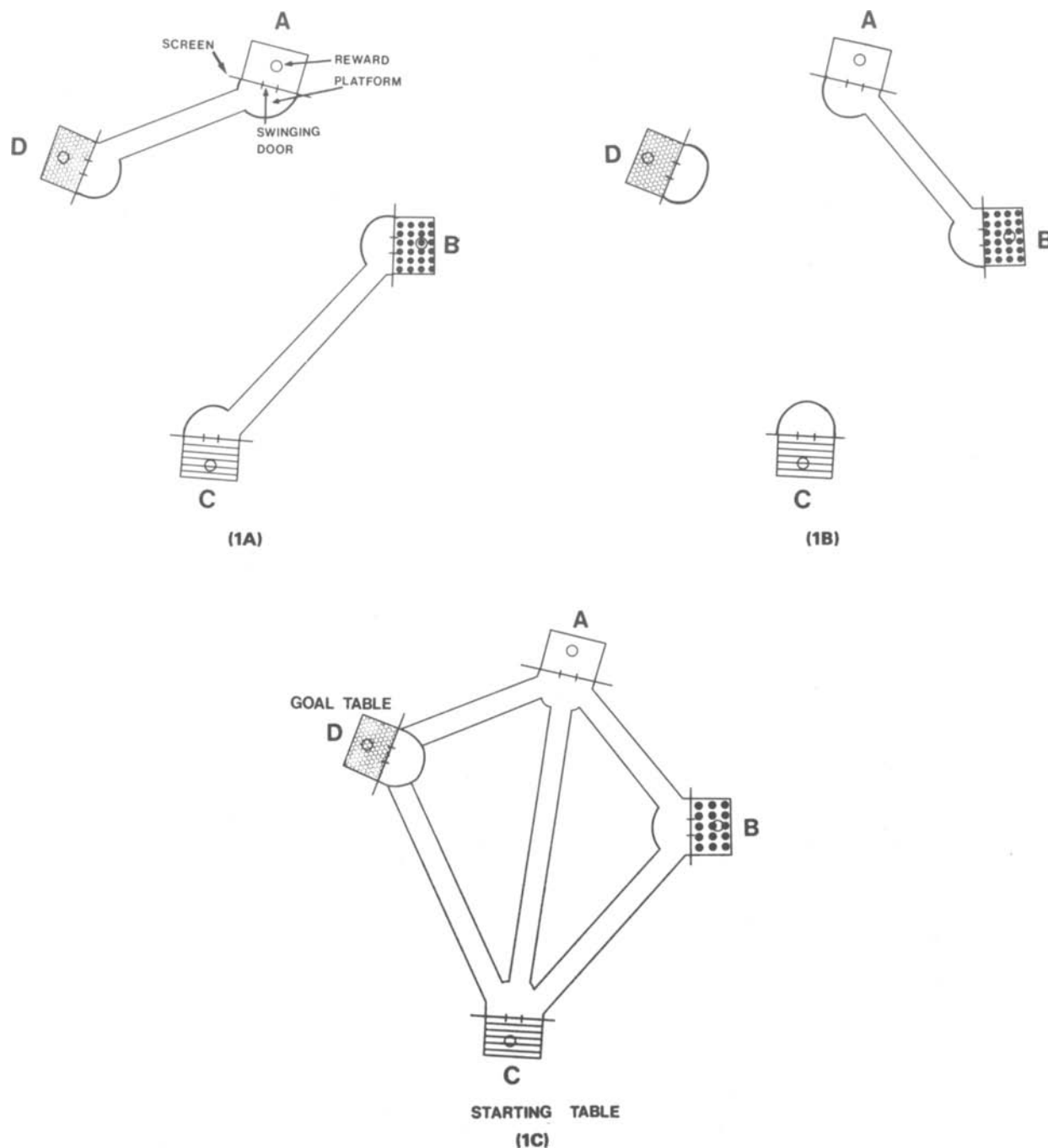


Figure 1. Example of a configuration used during the first phase of the experiment (1A), during the second phase for the experienced group (1B), and for the test (1C).

Each subspace consisted of two tables related by a runway. We used four tables (A, B, C, and D) and six movable pathways, which connected the tables according to the particular experimental condition (see below and Figure 1). The tables differed in texture and pattern. Each one was faced with a white cardboard screen that hindered observation of one table from another. Entrance to each table was possible through a swinging door in the screen. Pathways differed only in length ($AB = 1.20$ m; $BC = 1.80$ m; $CD = 2.00$ m; $DA = 1.30$ m; $AC = 2.40$ m; $BD = 1.96$ m). The ap-

paratus (elevated 1 m above the floor) was housed in a room relatively rich in environmental cues such as windows, file cabinets, and doors.

During the first phase of the experiment, the four tables were connected in pairs by simple pathways. For half of the subjects, A was connected to B and C was connected to D; for the other half, B was connected to C and A was connected to D (see Figure 1A). Each hamster received one daily session of 8 trials for 8 days (64 trials). At the beginning of each trial, the subject was placed on

one of the tables, which had been baited with hazelnuts, and was allowed to eat some of the nuts. This table served as the goal table for that trial. Then the hamster was carried to the starting table, which was connected to the goal table by a pathway, and was allowed to go to the goal table. The two tables served alternately as starting table and goal table for 4 trials. Then the hamster was run for 4 trials on the other two tables and the pathway between them.

In the second phase, which began on Day 9, the subjects were randomly assigned to either the experimental group ($n=26$) or the control group ($n=20$). Males and females were distributed equally between the groups. For animals in the experimental group, the two pathways used during the first part of the experiment were removed and a new connection was established between two adjacent but previously unrelated tables (see Figure 1B). For four trials, the subjects were allowed to run from one table to the other as in the first phase. The animals in the control group were not given these four trials. On the same day (Day 9), the two groups were given a shortcut test. New pathways were used to link the tables (an example is shown in Figure 1C). At the beginning of the test trial, food was presented to the hamster on the goal table, which was one of the two tables not visited by the experimental group during the four previous trials. The starting table was an adjacent one, also not visited during the second phase, to which the diagonal was connected. From this starting table, the animal could choose among three paths: the direct path leading to the goal table (i.e., the shortcut); the diagonal; and the path with which the animal had had previous experience, since it had been one of the pathways used during the first phase of the experiment. The trial lasted until the animal found the food on the goal table. We scored a "shortcut response" when the animal (1) chose the direct path immediately, or (2) chose the direct path after running along one of the two longer paths, provided that the animal retraced its steps spontaneously before reaching a fictive line halfway between the starting table and one of the nongoal tables. As soon as this line was crossed, whatever the animal's later behavior, a response corresponding to the first chosen path was scored. It must be emphasized that only in a few cases did animals return to the starting table after visiting a nongoal table. They usually went ahead until they reached the food. On Day 10, the shortcut test was repeated.

There were eight possible shortcuts, four for each of the two combinations of tables connected by a simple pathway in the first phase of the experiment: A to D, D to A, B to C, and C to B for the combination AB/CD, and A to B, B to A, C to D, and D to C for the combination AD/BC. Different subjects were presented with different shortcuts, following a counterbalanced design. Pseudorandom sequences were used to determine, within each day, the order of the subjects and the order of the subspaces explored during the first phase.

For the test trials, the possible effect on pathway choice of olfactory marks deposited on the familiar pathways was neutralized by interchanging, according to a pseudorandom sequence, the placements of the three runways from the starting table. This was possible because each runway was constructed with sliders that allowed its length to be modified.

RESULTS

Figure 2 presents the percentages of animals in each group that chose shortcuts during the two test trials on Days 9 and 10. In the first test trial, the shortcut was chosen by 50% of the hamsters from the experimental group and by 15% of those from the control group. In the second trial, the shortcut was chosen by 77% of the experimental animals and 45% of the control animals.

The diagonal pathway was seldom chosen—by 15% and

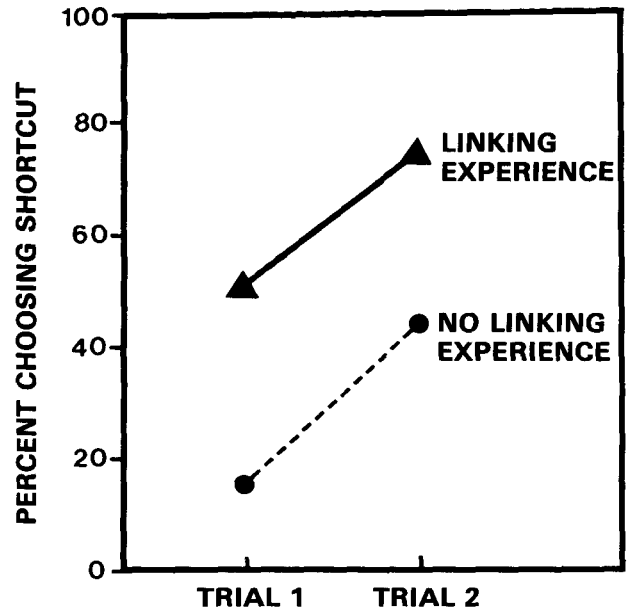


Figure 2. Percentages of animals in each group that chose shortcuts during the two test trials.

10% of the animals from the experimental and control groups, respectively, in the first trial, and by 11.5% and 10% of the animals from the experimental and control groups, respectively, in the second trial. Because of these low and stable rates, the choices of the diagonal and the longest pathway have been pooled for the analysis.

Chi-square statistics were calculated to compare the results of the two groups in each trial. The chi-square values are significant for both of them [first trial, $\chi^2(1) = 4.66$, $p < .05$; second trial, $\chi^2(1) = 3.97$, $p < .05$]. Furthermore, the sign test shows a significant improvement over trials within each group (experimental group: $N = 9$, $x = 1$, $p = .0195$; control group: $N = 8$, $x = 1$, $p = .0352$).

In the second trial, the control group reached the level achieved by the experimental group on the first test trial, that is, just after the four previous connecting trials: a comparison of the experimental group's performance on the first test trial and the control group's performance on the second test trial did not show any significant difference [$\chi^2(1) = 0.0015$, n.s.].

Figure 3 presents the details of the evolution of performance in the two groups. Only 19% of the 50% of the hamsters from the experimental group that gave an incorrect response on the first trial failed to improve their performance on the second trial. In the control group, a larger proportion (50% out of 85%) persisted in choosing the familiar, longer pathway on the second trial.

DISCUSSION

The aim of this experiment was to examine, in hamsters, the role of exploration in the integration of two previously

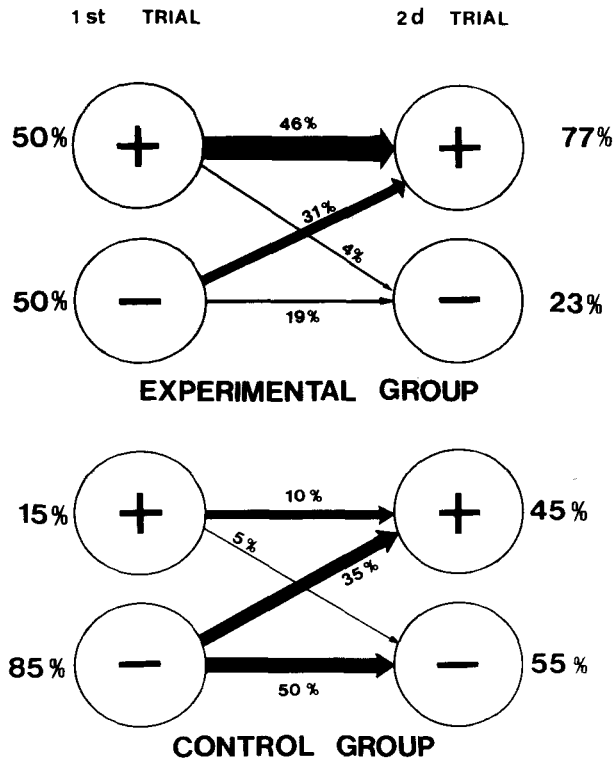


Figure 3. Evolution of performance by the animals of each group over the two test trials.

separated parts of space. Would the pretest exploration of a pathway connecting two subspaces lead the subjects to consider these two subspaces as parts of a unique space? The results show that after experience with a path linking two distant portions of two previously and separately explored spaces, hamsters are more likely to choose a newly offered shortcut path from the proximal portion of one environment to a goal in a nearby portion of the other. That shortcut did not traverse the linking path with which the animals had had experience or either of the two distant portions whose linkage had been experienced. Furthermore, although a large proportion of subjects from the control group persevered in the choice of the longer path during the second trial, nearly equal proportions of animals from both groups improved their performance from the first to the second trial. Thus, the exploration of the connecting pathway during the first trial appears to have facilitated the combination of separate parts of space into a whole, since animals from the control group reached, on the second trial, the level achieved by those in the experimental group on the first trial.

These results are consistent with those of previous studies demonstrating, in other species and with more or less different procedures, the crucial role of exploratory experience in spatial knowledge. Maier's three-table task, for example, has been extensively used to study spatial problem-solving abilities in rats. In these experiments, animals are generally given a preliminary exploratory

period in which they investigate, either entirely or partially, the apparatus, which consists of three tables in a triangular arrangement and their interconnecting runways. Subsequently, the animals are fed on one of the tables for a few minutes. They are then placed on another table for the test trial. The task is to return directly to the table on which they have just been fed. Since Maier's (1929) pioneer investigations, several analytical studies have been conducted with this apparatus. It has been shown that a prior exploration of the apparatus is a prerequisite to the exhibition of problem-solving behavior (Ellen, 1980). In addition, the whole apparatus must have been investigated: exploration of either the runways only or the tables only leads to unsuccessful performance (Ellen et al., 1982). In another experiment (Ellen, Soteres, & Wages, 1984), rats were allowed to explore either one or two tables of the apparatus on successive days. The test was administered after all the tables and runways had been explored in this piecemeal fashion. Only animals that were presented with pairs of tables and their interconnecting runway were able to solve the problem. No rat that explored only one table and runway per day succeeded in the task.

In a recent experiment, Chapuis and Varlet (1987) showed that Alsatian dogs are able to take a shortcut (AB) in an outdoor situation after they have been given exploratory experience of a longer path (ADB) and of two baited points (A and B). When released from point D, the dogs were able to find the food in both places, taking the shortcut (AB) they had not experienced before. This result obtained in an outdoor situation, that is, without delimited pathways, suggests that dogs are capable of evaluating, along a continuum, the direction of invisible goals by integrating motor and sensory cues obtained during an early but indirect visit to these goals.

All of these data converge to demonstrate that exploration allows the exhibition of performance that is not dependent upon successively processed information. Furthermore, the fact that in our experiment a linking experience has an effect that is generalized to an unexplored part of the apparatus suggests that at the time of the response there is a reorganization of previously acquired spatial knowledge. Instead of following a "route," animals allowed an additional exploratory experience produced an original response, perhaps based on the use of a map of the situation, indicating the localization of the goal.

One question concerns the definition of exploration. According to Ellen (personal communication, July 1985), the presence of a reward on the tables, and the intervention of the experimenter, who removes the animals and puts them on a starting table after they get the reward, does not allow actual exploration as a totally free behavior. In fact, the hamsters in the present experiment—and this may be a main difference between rats and hamsters—although motivated to get the reward, spent much time exploring while going from one table to another. We observed, mainly at the beginning of the experiment and in

the pretest phase for the experimental group, many stops, head movements, sniffings, and so forth. Learning that a reward is on a table behind a screen does not appear to inhibit exploratory behavior. We had already observed in hamsters (e.g., during visual discrimination learning) the tendency to interrupt ongoing behavior to investigate some details of the apparatus that were irrelevant to the task (unpublished observations).

In conclusion, exploration can be conceived to some extent as a manipulation of the environment leading to the extraction of spatial invariants; this idea is suggested by the present results and by other data. All of these experiments aimed to determine the effects of exploration on spatial performance. It remains now to analyze the underlying mechanisms of this apparently unorganized behavior, the result of which is, in some cases, the construction of a coherent spatial representation.

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