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SOME SPATIAL FACTORS IN LATENT INHIBITION



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requirements for the Degree of
Doctor of Philosophy

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Abstract

A variety of behavioral and physiological evidence suggests that animals possess internal "maps" which represent the spatial disposition of the environment. Besides the obvious function of navigation, researchers have argued that these maps also function as a novelty detection system. The idea here is that an event is novel if it does not match what the animal's map predicts to be in the location where that event occurs. Since an animal is more likely to learn about a novel event than a familiar one, this view suggests that the location of an event should be an important determinant of what the animal will learn about that event. The present series of experiments tested this view by examining the effects of changing the location of a preexposed flavor stimulus on aversion conditioning of that flavor. Typically, preconditioning exposure to a stimulus has been found to retard learning involving that stimulus, an outcome known as "latent inhibition." In all four experiments reported here, manipulations which changed the location of the preexposed flavor were found to attenuate latent inhibition for that flavor. These results indicate that the location of the preexposed stimulus is an important factor in latent inhibition, and suggest that event location is more important in learning than has previously been recognized.

Abbreviations

CS - conditional stimulus

ip - intraperitoneal

M - moles

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"...the blind and the deaf can usually manage to look after themselves, but not those who suffer from spatial confusion."

(Ross, 1975, p. 108)

There now exists a variety of data which suggests that animals build internal "maps" of their environment (Menzel, 1978; O'Keefe & Nadel, 1978). The research to be reported in this dissertation is concerned with testing some of the implications of that idea for our understanding of animal learning and behavior. In addition to providing the basis for animals' navigational abilities, researchers interested in cognitive mapping have argued that a memory system for spatial information could also serve as a foundation for other cognitive processes which are less obviously spatial in nature, like novelty detection. Since most psychologists would agree that novelty is important for learning, it seems worthwhile to examine the idea that the novelty of an event may depend on where it is located in the environment. Accordingly, a series of experiments was undertaken to examine the effects of changing the location of a familiar stimulus on subsequent learning involving that stimulus. Before describing this research and its implications, however, it will be useful to spend some time considering the idea that animals build cognitive maps which represent the spatial disposition of their environment.

A brief history of cognitive mapping

The idea that animals learn about the topography of their environment is not a new one. Tolman (1932, 1948) was one of the first to suggest this when he proposed that rats build "cognitive maps" of their environment. Based on his observations of rats in a variety of

maze tasks, Tolman concluded that rats learn about the spatial disposition of objects and places in the environment, and that they use this information to solve the problems set for them by psychologists. Furthermore, he argued that the properties of such place learning were different from those associated with other types of learning, like stimulus or response learning (Tolman, 1949). Tolman's ideas garnered little favor among psychologists at the time when he proposed them. Mainstream psychology was strongly in the grip of behaviorist thinking and the branding, and researchers felt little call to re-introduce the sorts of "mentalistic" terminology they had sought to banish from the description and analysis of behavior. A long, and sometimes bitter, debate ensued over the question of whether the rat in the maze learned about places or responses in mastering the task (cf. Munn, 1950). In the end, the controversy was "resolved" in favor of stimulus-response (S-R) theory when Restle (1957) suggested that place learning was the same as response learning, except that it depended on distal rather than proximal stimuli. There was no longer any reason to talk of place learning as something separate from response learning, and the notion of cognitive mapping disappeared from the literature.

This situation has changed markedly in the last decade, however, and questions concerning animals' spatial abilities and knowledge are once again being investigated by psychologists (e.g., Menzel, 1978). In part, the resurgence of interest in place learning and cognitive mapping can be attributed to the changing intellectual climate in animal psychology. Inspired by the success of their colleagues in applying cognitive concepts and formulations to the problems of human

learning and memory, many researchers interested in animal learning have adopted a somewhat more cognitive orientation toward the study of behavior and are no longer so reluctant to allow the animal an active role in the learning process (e.g., Hulse, Fowler, & Honig, 1978). A greater willingness to consider cognitive processes as possible determinants of behavior is insufficient to explain the renewed interest in cognitive mapping, however. Psychologists still try to make do with simpler explanation whenever possible. Rather, the revival of the notion of cognitive mapping is due to the fact that the assimilation of place learning to simple distal cue learning has not done justice to the sorts of observations which one would regard as examples of place learning.

There are two sorts of problems which arise in interpreting place learning as distal cue learning. First, it does not explain why place learning appears to be so much more rapid and flexible than other sorts of learning. A good example of the flexibility associated with place learning comes from Menzel's work with chimpanzees. Using a variant of the delayed-response paradigm, Menzel (1973) investigated the chimp's memory for the location of food in its environment. On any given trial one of a group of six chimps was carried around the one-acre enclosure where they lived and allowed to watch an experimenter hide 18 pieces of food in various randomly selected locations. The chimp was then reunited with the rest of the pack, who hadn't seen the food being hidden. After a short delay, the chimps were released as a group and allowed to collect whatever food they could find within an hour. Invariably, the chimp who saw the food being hidden found much more of the food than the

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uninformed controls. Over the 16 test trials that were run, the informed chimp found an average of 12.5 pieces of food per trial. The controls, on the other hand, found a grand total of 17 pieces of food over all 16 trials (an average of .21 pieces of food per animal on a trial). The most striking aspect of the informed chimp's behavior, however, was the way it went about the task. When released, the chimp would run to a cache, eat what it contained, run directly to another cache, etc. The chimp rarely returned to a site from which it had already collected the food, but would repeatedly search a site if a control had already stumbled across the food in that location. Moreover, an examination of the routes taken by the informed chimps showed that they were not retracing the random route taken by the experimenter in hiding the food. Rather, the routes taken by the informed chimps were best described as being organized according to a least distance principle. Further experiments showed that the area which would be searched first by a chimp could be predicted on the basis of food density or type of food available in an area. It thus appears that the chimp has a very good memory for things it has seen, where those things are in relation to other things in the environment, and where it is in relation to any of those things. A distal cue interpretation might account for some aspects of the chimps' behavior in this task, but it certainly doesn't explain the nature of the routes taken by the informed chimps, nor the chimps' ability to take into account food density or type in organizing their routes.

Similarly, a distal cue interpretation of place learning provides little in the way of a rationale for the rapidity of place learning.

Wilz and Bolton (1971) gave gerbils a single 15-min exposure to an open field containing a group of objects which stood in a particular spatial arrangement relative to one another and to the walls of the open field. The gerbils were then transferred to an identical open field containing those objects in either the same configuration or a different one. Wilz and Bolton found that the gerbils spent more time exploring the objects when they were in a different configuration (hence in different locations) than when they were left in the same configuration. In fact, changing the spatial arrangement of the objects evoked as much exploration as had occurred during the gerbils' initial exposure to the objects. Wilz and Bolton replicated this finding in a second experiment in which gerbils were exposed and tested with only a single object in the open field. Changing the location of the object relative to the walls of the open field again evoked renewed exploration of the object. Gerbils thus seem to learn the spatial disposition of objects with only minimal exposure to a situation. Within a S-R framework, response learning is seen as a gradual, incremental process. There is no a priori reason why learning based on distal cues should be any more rapid than learning based on proximal cues.

The Wilz and Bolton (1971) study raises a further question. A distal cue interpretation of place learning can be plausibly applied to tasks which require or foster the use of place "strategies" to obtain reinforcement. It's not clear, though, how this view should be applied to instances of place learning in situations where there is no task for the animal to solve. Yamamoto, Wapner, and Stevens

(1980) gave rats an 8-min exposure to an open table containing a variety of objects on each of 12 consecutive days. On the 13th day, the rats were tested for their knowledge of the locations of the objects on the table. Half the rats were tested on an unchanged table. For the remaining rats, some of the objects were exchanged with one another or deleted from the table, while others were left in their original locations. Yamamoto et al. found that rats tested on the changed table selectively reexplored those objects which had been exchanged with one another, and those areas which no longer contained objects. However, they spent no more time investigating objects left in their original locations than did rats tested on the unchanged table. The fact that they explored areas no longer containing objects suggests that the rats "expected" to find objects in certain locations. Further, the fact that they explored an object in a location which previously held a different object indicates that they had some idea of what object should be found in a particular place. It would appear that rats acquire a rather detailed knowledge of the topography of an environment even when they are not required to do so.

In addition to conceptual problems in reducing place learning to distal cue learning, there are also practical problems in applying a distal cue interpretation to many place learning tasks. Part of the attractiveness of the distal cue view is that it purports to explain a more complex phenomenon in terms of a simpler process. This simplicity turns out to be more illusory than real. Although readily applicable to simple T- or Y-maze tasks, a distal cue interpretation of place learning becomes quite convoluted when applied to a task like

place learning in a circular maze (O'Keefe, Nadel, Keightley, & Kill, 1975). First, the animal cannot run towards (or away from) distal cues for more than a short segment of the runway. Second, the animal must make a number of complex conditional discriminations if it is to differentiate one part of the maze from another. Finally, the animal must learn to respond at a site which is different from that of the cue controlling the response, a situation which gives animals an inordinate amount of difficulty in discrimination learning tasks (Covey, 1968; Miller & Murphy, 1964). On the basis of these considerations, one would have to predict that place learning would be a very difficult task for the rat on a circular maze, which is not the case at all (O'Keefe *et al.*, 1975).

By themselves, none of these concerns are sufficient to force rejection of a distal cue interpretation of place learning. Taken together, though, they provide good reasons for thinking that there is something more to place learning than simple distal cue learning. The important issue then becomes that of the mechanisms which underlie place learning. Other than likening the animal's spatial knowledge to that contained in a map, Tolman never formalized the idea of place learning to any great extent. He thus left unanswered a host of questions concerning how animals acquire, represent, and utilize spatial information. Similarly, much of the contemporary research on cognitive mapping is more properly viewed as descriptive than analytic. Studies of exploration like those of Wilz and Bolton (1971) and Yamamoto *et al.* (1980) indicate that the animal's representation of its environment is a spatial one, but they do not explain how such

representations are possible. Likewise, studies of spatial memory (e.g., Beatty & Shevalia, 1980; Maki, Brokovsky, & Berg, 1979; Roberts, 1979) have revealed that the rat's memory for where it has been is far more resistant to interference and decay than its memory for other sorts of environmental information, but, provide no rationale for why that is the case. Thus, although researchers have recognized the existence of place learning, the basis and nature of that ability, have not been well-understood.

Physiological basis of cognitive maps

Some recent work in the neurosciences should help to advance our understanding of place learning. As it turns out, Tolman's map analogy may have been more than appropriate. It now appears that there is some neural reality to the idea of a cognitive map. Studies of single-unit activity in the hippocampus of freely-moving rats have revealed the existence of cells with rather unique spatial properties (O'Keefe, 1976; O'Keefe & Dostrovsky, 1971; Olton, Branch, & Best, 1978; Ranck, 1973). Whereas cells with spatial properties in other brain areas seem to be encoding information about where things are in relation to the animal's body (i.e., egocentric space), many of the cells in the hippocampus appear to be encoding information about the spatial relations among objects in the environment (O'Keefe, 1979). To date, three types of spatial cells have been recorded from the hippocampus. The first type of cell, the "place" cell, fires only when the animal is in a particular place in the environment, with different cells firing in different parts of the environment. Observations of the animals suggested that these units were coding the animal's location

in the environment, as the activation of a unit in a particular location seemed to be independent of the animal's behavior or orientation in that place.

A recent study by O'Keefe and Conway (1978) has confirmed these earlier impressions of the factors controlling the activity of place cells. O'Keefe and Conway recorded place units from rats while they were performing a place discrimination task which required them to visit all three arms of a T-maze located inside a controlled-cue environment. On the walls of this environment were four cues (a light, fan, buzzer, and card) which stood in a fixed relationship to one another and to the arms of the T-maze. Place units were also recorded from the rats while they were on an open platform in another part of the room. By changing various aspects of the environment and task, O'Keefe and Conway were able to rule out a number of factors which might have been controlling a unit's activity, like the animal's behavior or orientation when it was in a particular part of the environment, the presence/absence of reward, or specific intramaze stimuli. Instead, they found that activation of a unit depended on where the animal was in relation to the wall cues, though not in any simple fashion. Removal of all the wall cues disrupted the spatial specificity of a unit's response, indicating that it was being controlled by these cues. No single cue, or subset of cues, appeared necessary for the activation of a unit, though. O'Keefe and Conway found that many of the place units would maintain their place fields as long as any two of the four wall cues remained in their original locations on the walls of the environment. The fact that any subset of

the wall cues was sufficient to activate a unit when the animal was in a particular place suggests that these cells were indeed coding the animal's location in the environment, and not a particular stimulus or configuration of stimuli.

The second type of unit which has been recorded from the hippocampus, the "misplace" cell, is really a variant of the place cell. Like the place unit, misplace cells fire only when the animal is in a particular place in the environment. They have the additional property, however, of firing maximally when some change has been made in the place corresponding to the unit's field, like the addition of an object to that location or the removal of an object which can normally be perceived when the animal is in that location. Misplace cells thus seem to be signalling change in a particular part of the environment.

Finally, a third type of unit has been recorded from the hippocampus, the "theta" or "displace" cell. Unlike place and misplace units, these cells do not have place fields in an environment. Rather, their activity bears a particular relationship to the hippocampal electroencephalogram (EEG). During "voluntary" movements like walking and rearing, the hippocampal EEG is characterized by a regular sinusoidal pattern known as the theta rhythm (Vanderwolf, 1969). Displace cells increase their firing rates whenever the theta rhythm is present in the EEG, regardless of where the animal is in the environment. Morris, Black, and O'Keefe (1976) suggested that the theta rhythm is conveying information about how far a particular movement would displace the animal in space, as they observed that the frequency of the theta rhythm varied as a function of the distance a rat was required to

jump. On these grounds, it seems reasonable to conjecture that the displace cells are providing distance information to the animal.

Data from lesion studies have also implicated the hippocampus in the processing of spatial information. Although animals with hippocampal damage show deficits in a variety of situations, their impairment is particularly profound in tasks requiring the utilization of spatial information. A good example of this difficulty comes from the O'Keefe et al. (1975) study mentioned earlier. O'Keefe et al. trained rats with damage to the fornix (a major input/output path of the hippocampus) to find water in one of two ways on a circular maze containing a number of water wells. For some rats, the well the animal had to lick at to obtain water was changed randomly, from trial to trial, but was always marked by a distinctive cue (a small light shining directly on the well). For other rats, the correct well remained in the same location relative to maze and room cues throughout the experiment, but the location of the light cue changed from trial to trial. Some rats thus had to solve the task on the basis of where the well was located in the room, whereas others had to solve it on the basis of a distinctive cue marking the correct well. The results were clear-cut. Rats with fornix damage were profoundly impaired relative to controls in solving the place-learning version of the task, and many of the animals (7/8) never solved the problem at all. When a distinctive cue marked the location of the correct well, however, fornix-damaged animals were actually somewhat faster than controls in solving the task. Hippocampal dysfunction, then, disrupted place learning while leaving cue learning intact or

even facilitated.

O'Keefe and Nadel (1978) have recently detailed a theory of hippocampal function which incorporates these sorts of observations and which emphasizes its role in processing spatial information. They argued that the hippocampus, working with inputs from other brain structures, creates and stores spatial maps of the environment. These cognitive maps capture the objective (nonegocentric) spatial relations among places and the objects they contain, and represent them as parts of a unified whole. Drawing on neuroanatomical data, O'Keefe and Nadel detailed a neural model for how the hippocampus might instantiate these sorts of maps. They also specified the properties of these maps in some detail, and showed how many of the effects of hippocampal dysfunction could be understood in terms of an underlying deficit in processing and utilizing spatial information. In developing their account of the effects of hippocampal damage on an animal's behavior, they made a number of suggestions about how normal animals use cognitive maps. Their work may thus offer some new insights into the mechanisms underlying animal learning and behavior.

Functions of a cognitive map

According to O'Keefe and Nadel (1978), a cognitive map is a representation of a part of space which incorporates information about the objects contained in some of the places making up that space, and which can be used to derive information about the direction and distance between any two places or objects in that space. Such maps are built up by the animal during its exploration of the environment. Exploration is triggered whenever an animal's map

does not match the current state of the environment. When the animal is first introduced to an environment, there is no basis for a match (as the animal has no map for that situation); and the situation will be explored. As the animal moves through the environment, the objects it encounters (good, bad, or indifferent) will be rapidly sited in its map on an all-or-none basis, with inputs from sensorimotor systems providing a coding strategy which allows objects to be sited in map locations that preserve their spatial ordering and distances in the environment. In addition to initiating map building, a match/mismatch system based on the contents of spatial locations allows the animal to revise already existing maps to reflect changes in the environment. Thus, alterations like the addition/deletion of objects from an environment, changes in the nature of an object in a location, or the relocation of an object in a different place will generate discrepancies which lead to exploration. As the map is revised, these discrepancies disappear and exploration ceases. When this happens, O'Keefe and Nadel suggest that the old map is not destroyed, only that a revised map becomes available. In this way, the animal's knowledge of its environment is kept up to date while some information about past states of the environment is retained.

Place strategies

The most obvious function for a cognitive map is that of navigation. With a map, an animal can travel from any place in an environment to any other point in that environment, even an unperceived one, by any of a number of routes. The nature of these maps makes it unlikely that the animal will become lost or confused as it travels from

place to place in the environment, because places are not defined in any simple fashion by the cues they contain. Rather, places are defined in terms of the network of redundant and relevant spatial relations which obtain among the cues in an environment. When the animal is in a particular place in an environment, the cues it perceives will stand in a unique spatial relationship to one another, regardless of the animal's orientation in its current location. The critical point here is that no particular cue is necessary for the animal to identify its location in the environment. Any cue, or group of cues, could be removed from the environment without altering the spatial relationships which obtain among the remaining cues. As long as some minimal number of cues remain, their spatial relations will serve to specify the animal's location (cf. O'Keefe & Conway, 1978). In this way, the animal always knows where it is, even in the face of a changing environment.

The flexibility and lack of confusion inherent in cognitive maps make them a powerful tool for problem-solving. Since objects are represented in a cognitive map in terms of where they occur, the animal can use its map to take it to those locations containing objects of interest or importance. Places containing desired objects (e.g., food, water, mate) can be approached from anywhere in the environment, by any available route. Similarly, the map can be used to avoid places containing dangerous things (e.g., predators, traps) or to escape from such places to safe ones. When the animal is attempting to solve a problem on the basis of where things are located in the environment, it can be said to be using a place strategy.

Such place strategies can be contrasted with other behavioral strategies based on other sorts of information. For example, an animal might learn to solve a given problem on the basis of a particular cue which it approaches or avoids regardless of where the cue occurs in the environment (a cue strategy). Alternatively, the animal could learn to make a particular response in the presence of a stimulus (a response strategy). According to O'Keefe and Nadel (1978), the difference between these various strategies lies not so much in the nature of the cues employed as in how they are employed. A cue in a given situation can be used by the animal as a component of its cognitive map, a cue to be approached or avoided in its own right, or as a signal for the performance of a particular response.

O'Keefe and Nadel argue that these strategies depend on different neural substrates, and that their interactions are best conceived of as competitive in nature. Furthermore, they suggested that the properties of these various strategies differ along a number of dimensions, like rate of acquisition, flexibility and persistence, susceptibility to interference, and ease of use, to name a few. The implication of their argument is clear; understanding the behavior of an animal requires some knowledge of how the animal is trying to solve the task. While some problems have been devised which force the animal to solve a problem in a given way (e.g., O'Keefe et al., 1975), most tasks used to study learning and behavior in normal and brain-damaged animals permit the successful use of more than one strategy. In such cases, it is necessary to give the animal "probe" trials which pit the various strategies against one another to determine how the animal is

solving the task (e.g., Barnes, Nadel, & Honig, 1980). The bulk of O'Keefe and Nadel's book is devoted to a consideration of these strategies and their role in various sorts of experimental tasks. In it, they showed that many of the effects of hippocampal damage could be understood in terms of the elimination of place strategies from the animal's repertoire and a forced reliance on cue and response strategies with different properties. By showing that the behavior of brain-damaged animals could be profitably analyzed in terms of different strategies with different properties, O'Keefe and Nadel have provided good reasons for thinking that a similar analysis of the behavior of normal animals may pay handsome dividends for our understanding of their behavior.

Novelty detection

Place strategies and place recognition are not the only functions for a cognitive map. A cognitive map also functions as a novelty detection system. To some extent, this point has already been alluded to in our discussion of how maps are acquired and modified. Whenever the environment does not match the animal's map of the situation, the discrepancy triggers exploration which leads to a revision of the animal's map. It's not hard to see that this sort of match/mismatch system is intimately related to the question of whether an event is novel or familiar. Researchers interested in exploration have long argued that questions concerning stimulus novelty can only be resolved with respect to the animal's past experiences in the situation where the stimulus occurs (Halliday, 1968; Shillito, 1963). The idea is that the animal is constantly trying to match its past and present

experiences in an environment. When they cannot be matched, novelty exists and the source of the discrepancy is explored. The point which needs to be emphasized here is that the representations on which these matches and mismatches are based are spatial in nature. Studies like those of Wilz and Bolton (1971) and Yamamoto *et al.* (1980) make it clear that the location of an event is an integral part of its novelty. In fact, almost any situation to which we could attach the label of novel can be represented as some sort of change in the spatial domain. By predicting what, if anything, an animal should find in a given location, a cognitive map provides the basis for a novelty detection system of considerable scope and sensitivity (Nadel & Willner, 1980):

This view of novelty as a matter of a discrepancy in a cognitive map has a number of implications for our understanding of novelty/familiarity effects in learning. Psychologists have long recognized that novel and familiar events differ not only in their effects on behavior, but also in their effectiveness in learning tasks. Within the contemporary learning literature, this idea most often finds expression in the suggestion that an animal is more likely to learn about a novel (surprising, unexpected) event than it is about a familiar or expected one (Mackintosh, 1978; Wagner, 1978, 1979). For the most part, researchers have approached the issue of novelty/familiarity effects in learning as a question of the extent to which an event is predicted by cues which precede it in time. While not denying the importance of predictive temporal cues in producing surprise, a cognitive map interpretation of novelty focuses attention on a somewhat different aspect of the problem, namely, what is being predicted by

those cues. Because a cognitive map represents things in terms of their location, a given event may be seen as novel or familiar depending on where it occurs. If an event occurs in a location where it has never occurred before, it is identified as novel and the animal will learn about that event. If the event occurs in a place where the map says it should be, however, it is treated as a familiar event, and the animal will be less likely to learn about it. On this view, an animal in a learning task is not merely learning to expect a certain type of event, but is forming an expectation of a particular event in a particular place. The implication of this is that where an event occurs may be at least as important as when it occurs in determining what the animal will learn about that event.

◆ There are data which suggest that learning the location of events is an integral part of almost any learning task. For example, Zener (1937) gave dogs pairings of a conditioned stimulus (CS) with food while they were restrained on a testing stand in a room. When they were tested on a new stand in that room, unrestrained dogs left the stand when the CS was presented and returned to the original testing stand to await the delivery of food. An even more striking example of this sort was reported by Beritoff (1965, p. 69). He presented dogs in a new room with a CS which had previously signalled the availability of food in another room and found that the dogs left the new room and returned to the site of the foodbox in the original training room. The data thus suggest that an animal's expectation of an event is often referenced to the location in which that event has occurred.

There are few studies which bear directly on the question of event

location and surprise in learning. The data which do exist are highly suggestive, though, and have come primarily from the study of stimulus preexposure effects in learning. It has become a frequent observation over the last two decades that nonreinforced exposure to a stimulus can retard its subsequent conversion into an effective excitatory or inhibitory CS, an outcome known as "latent inhibition" (Lubow, 1973). Procedurally, studies of latent inhibition are much like those of exploration; the animal is simply exposed to a stimulus in the same location on a number of occasions. One might therefore think that the retardation of learning which can follow stimulus exposure would be analyzed in terms of the familiarity of the stimulus. This hasn't been the case, however. Typically, the effect has been attributed to the fact that the animal's initial experience with the stimulus is nonreinforced. The animal learns that the stimulus is not correlated with other events, and comes to ignore it as "irrelevant" (Mackintosh, 1973, 1975). Having learned that the stimulus is irrelevant, the animal then learns more slowly that it is a reliable signal for the occurrence or nonoccurrence of other events. A cognitive map interpretation of latent inhibition, on the other hand, attaches no special importance to the irrelevance of the preexposed stimulus in producing the effect. Instead, it emphasizes the location of the preexposed stimulus as the crucial determinant of latent inhibition. All events, regardless of their nature or predictive power, are represented as occurring in particular locations. As long as a stimulus continues to be presented in the same location, the map will identify it as familiar and learning will be retarded. This view leads to two predictions concerning the

effects of stimulus exposure on learning. First, it asserts that even a predictive stimulus will lose associability when it continues to be presented in the same location. Second, it predicts that changing the location in which a preexposed stimulus is presented will restore its associability and disrupt latent inhibition, as the map would identify the old stimulus in a new location as novel. The available evidence is consistent with both these predictions.

Hall and Pearce (1979) recently reported that exposure to a stimulus could retard later learning even when the stimulus predicted a reinforcer during the exposure phase. In their experiment, rats initially received pairings of either a tone or a light with weak shock. During subsequent phases of the experiment, all the rats received pairings, first the tone, then the light, with a stronger shock. Hall and Pearce found that rats for whom the tone was novel when it was paired with a stronger shock (i.e., rats who initially received light-weak shock pairings) were faster to acquire suppression to the tone than rats who initially received tone-weak shock pairings. Conversely, rats given tone-weak shock pairings conditioned more readily to the light when it signalled a stronger shock than did rats who had received prior pairings of the light with the weak shock. Subsequent experiments ruled out the weakness of the pretraining shock as the cause of this effect. Since one would expect that prior pairings of a stimulus with shock would facilitate later learning when the stimulus signalled a stronger shock, the retardation of learning observed in this experiment would seem to constitute strong evidence that non-reinforcement of the preexposed CS is not essential for latent inhibi-

tion.³ This is not to say that nonreinforcement does not contribute to the effect. Hall and Pearce also observed that simple tone preexposure produced an even greater retardation of learning than that which occurred when the CS was initially paired with a weak shock. Although the presence/absence of reinforcement may affect the magnitude of latent inhibition, it is nevertheless clear that the processes which mediate latent inhibition operate in both the presence and absence of reinforcement. These data are quite compatible with a cognitive map interpretation of latent inhibition, but raise serious difficulties for a learned irrelevance account of the phenomenon.

Data from context shift experiments provide some support for the second prediction of cognitive map theory. A number of investigators have reported that the effects of stimulus exposure on learning depend on where training takes place. Anderson, O'Farrell, Formica, and Caponigri (1969) reported that rats showed less evidence of latent inhibition when they were conditioned in an environment different from the one in which they were exposed to the CS. There have even been reports that stimulus preexposure can facilitate later learning when training is conducted in a place other than the preexposure environment. Gibson and Walk (1956) and Hall (1979) reported that preexposing rats to objects in their home cages facilitated the rats' mastery of a discrimination between these objects in a T-maze. An especially impressive example of the importance of environmental context in stimulus exposure effects comes from a study reported by Lubow, Rifkin, and Alek (1976), who found that identical stimulus exposure could either retard or facilitate learning, depending on where training took place. Lubow

et al. preexposed rats to one of two odours in one of two environments in a factorially designed experiment. The rats were then trained in either the same environment or a novel one on an odour discrimination task in which they had to discriminate an unscented tube from one containing either the preexposed or the novel odour. Lubow et al. found that rats trained in the preexposure environment with the preexposed odour were slower to master the task than rats trained with the novel odour. Just the reverse held true when the rats were trained in a novel environment. Here, rats trained with the preexposed odour were faster to master the discrimination than rats trained with the novel odour.

Insofar as a change of environment necessarily involves a change in the location of the preexposed stimulus, the results of these context shift experiments can be considered support for a cognitive map interpretation of latent inhibition. They cannot be considered definitive, however. The problem is that the disruptive effects of a context shift on latent inhibition can also be interpreted in ways other than that of a shift in the location of a preexposed stimulus. For example, Lubow et al. (1976) suggested that the context shift manipulation they employed was effective because it led to the creation of a contrast between the absolute novelty of the preexposed stimulus and that of the environment in which it was presented. The idea here is that a condition of contrasting novelty of stimulus to environment is a more effective condition for learning than the lack of such a contrast. Similarly, the disruptive effects of a context shift could be attributed to the absence of environmental cues associated with

the animal's initial exposure to a stimulus. Wagner (1978) suggested that associations are formed between a stimulus and "contextual" cues (usually environmental ones), and that the presence of these cues serves to "prime" a representation of the preexposed stimulus into short-term memory. Once primed, the stimulus is not processed or rehearsed to the same extent that it would be if it wasn't primed. There are thus at least three separate accounts which can be put forward to explain the disruptive effects of a context shift on latent inhibition.

Because of this ambiguity, the experiments to be reported in this dissertation were undertaken to further examine the contribution of CS location to stimulus preexposure effects in learning. In asserting that the novelty or familiarity of an event depends on its location, cognitive map theory predicts that changing the location of a preexposed stimulus within the preexposure environment should disrupt latent inhibition. The present experiments tested this idea by examining the effects of both within- and cross-context shifts in the location of a preexposed taste CS on conditioning of an aversion to that flavor. The choice of the taste aversion paradigm for these experiments was guided by two considerations. First, robust preexposure effects have been observed in taste aversion learning (e.g., Elkins, 1973; Revusky & Bedarf, 1967). The retardation of aversion conditioning that follows taste preexposure has often been interpreted in terms of a process of "learned safety" (Kalat & Rozin, 1973) rather than latent inhibition. Although subsequent research has discounted a learned safety account of taste preexposure effects (e.g., Best, 1975; Best & Gemberling, 1977), it is not yet clear that the same processes mediate preexposure effects with

gustatory and nongustatory stimuli. By employing manipulations known to affect latent inhibition in more traditional paradigms, the present experiments may provide further insight into the extent to which the mechanisms underlying preexposure effects with gustatory cues are like those mediating similar effects in research with nongustatory cues.

A second reason for using the flavor aversion paradigm in these studies was the practical advantages it offers for studying the effects of location shifts on latent inhibition. The characteristics of a cue like a tone or a light may be dramatically altered by a change in its location. Because of this, special care must be taken to insure that a change in the location of a stimulus is not also a change in its physical quality. The use of gustatory stimuli in these experiments circumvents this potential problem; a taste stimulus can be presented anywhere in an environment without altering its physical properties. In this way, any disruptive effects of a location shift on latent inhibition can be unambiguously attributed to the change in location of the preexposed taste CS.

Experiment 1

This first experiment was designed to determine whether accounts of latent inhibition like those of Wagner (1978) and Nadel and Willner (1980) are applicable to the analysis of flavor preexposure effects in aversion learning. This issue is not a trivial one, for researchers have often held that acquired food aversions represent a unique type of learning with its own laws, and that nongustatory cues are of little or no consequence in this type of learning (e.g., Rozin & Kalat, 1971;

Seligman, 1970). With respect to flavor preexposure effects in aversion learning, researchers have traditionally maintained that exposure to a flavor retards later learning because the animal learns that the flavor is "safe." Originally put forth as an explanation for the delay gradient in flavor aversion learning (cf. Kalat & Rozin, 1973), the idea is that the animal processes the novel flavor as if it expected that flavor to make it ill. When illness does not follow consumption of the substance, the animal actively learns that the flavor does not predict illness. Effectively, the claim is that nonreinforced exposure to a flavor CS turns that flavor into a conditioned inhibitor for illness. The retardation of learning that can follow exposure to a flavor, then, has been explained in basically different terms than those used to account for similar effects with nongustatory cues.

There are grounds for disputing all these claims. After reviewing the available evidence, both Revusky (1977) and Logue (1979) suggested that the differences between flavor aversion learning and other types of learning are more quantitative than qualitative. Similarly, Batson and Best (1979) and Willner (1978) have presented evidence that exteroceptive cues can be associated with illness and that such cues are capable of "blocking" (Kamin, 1969) the establishment of a taste aversion. In the case of flavor preexposure effects, Best (1975) has shown that learned safety is not an appropriate interpretation of those effects. Best found that simple exposure to a flavor did not turn that flavor into a conditioned inhibitor. In fact, he found that preexposure to a flavor retarded its conversion into an effective inhibitor. The fact that flavor preexposure retarded the establishment of that flavor

as an inhibitory stimulus suggests that similar processes underlie stimulus exposure effects with gustatory and nongustatory cues.

The present experiment provides further evidence on this question by testing a prediction derived from current accounts of latent inhibition. Although very different in their details, the accounts of latent inhibition offered by Wagner (1978) and Nadel and Willner (1980) share a common emphasis on the importance of environmental context in mediating the effects of stimulus exposure on learning. Both views, for example, predict that conditioning a preexposed taste in an environment other than the one in which it was exposed will disrupt the detrimental effects of flavor exposure on aversion learning. If this is the case, there will be good reasons for thinking that the processes underlying the effects of flavor preexposure are the same as those mediating similar effects with nongustatory cues.

In this experiment, two groups of rats were exposed to a saccharin solution on a number of occasions prior to experiencing a pairing of that solution with illness. One of these groups was preexposed to saccharin in a novel environment, whereas the other group was exposed to saccharin in their home cages. Following this, the rats received a saccharin-illness pairing in their home cages. If environmental context is important in determining the effects of flavor preexposure, rats preexposed to saccharin in a novel environment and conditioned in their home cages should form stronger saccharin aversions than rats both preexposed and conditioned in their home cages. By comparing these groups with no-preexposure controls, it should also be possible to determine the extent to which a context shift disrupts the effects

of flavor preexposure on aversion learning.

The choice of the rats' home cages for conditioning environments in this experiment was dictated by some recent data reported by Rudy, Rosenberg, and Sandell (1977). Rudy *et al.* found that exposing an animal to novel stimulation just prior to pairing a preexposed flavor CS with illness could attenuate the flavor preexposure effect, presumably by increasing general arousal. Conditioning a preexposed flavor in a novel environment, then, could be expected to disrupt the flavor preexposure effect independently of any other role the context might play in mediating those effects. The present experiment sought to dissociate these two possible effects of a context shift on the flavor preexposure effect by conditioning all the animals in a familiar environment.

Method

Subjects. The subjects were 30 naive male hooded rats weighing 350-400 g at the start of the experiment. They were individually housed in sheet metal and wire mesh cages measuring 25 x 18 x 18 cm, with free access to blocks of lab chow throughout the experiment. The lights in the housing room were on from 0700-2100 hr daily.

Apparatus. In addition to the rats' home cages, two other environments were also used in this experiment. Ten clear plastic environments measuring 46 x 26 x 16 cm were used as preexposure environments for some of the rats in this experiment. These cages had wire mesh tops, contained 3 blocks of lab chow, and were located on the floor in another part of the housing room. Ten sheet metal and wire mesh cages measuring 45 x 25 x 18 cm were also used as holding cages for some of the rats.

These cages provided unrestricted access to blocks of lab chow and were located on a separate rack in the housing room.

During preexposure and conditioning sessions, the rats drank fluids from small brass drinking cups 3 cm in diameter and 1 cm deep. These cups were centrally mounted on 7.5 x 7.5 cm squares of sheet metal which were painted gray.

Procedure. The rats were initially maintained on free food and water for 6 days, during which time they were handled daily. Adaptation to water deprivation took place over the next 15 days. During this period, the rats' daily access to tap water in graduated plastic tubes was restricted to a single 20-min period beginning approximately 2 hr after their daily weighing at 0930. Throughout the experiment, each rat's consumption of tap water was measured to the nearest .5 ml. The rats were trained to ingest fluid from either the left- or right-front portions of their home cages by daily alternation of the location at which water was presented. The rats were also adapted to the injection procedure during this phase of the experiment. On the last 2 days of the adaptation period, the rats were given intraperitoneal (ip) injections of 2 ml of physiological saline after they were weighed. They were then assigned to three groups (n=10) matched for average fluid consumption over the last 5 days of the adaptation period.

Two groups of rats, Groups Shift and HC, were preexposed to a saccharin solution on each of the next 5 days. After their daily weighing, the rats in Group Shift were removed from their home cages and placed in the clear plastic environments. There they were allowed 20-min access to 2 ml of a .15% sodium saccharin solution presented in

a drinking cup along one of the end walls of the environment. They were then returned to their home cages, and the plastic environments were cleaned. The rats in Group HC, on the other hand, received similar access to saccharin from drinking cups presented in their home cages. At the end of the 20-min preexposure period, the cups were removed from the cages and the rats were placed in the holding cages for almost 24 hr. They were returned to their home cages just prior to the start of the next preexposure session. The rats in the third group, No Pre, were not preexposed to saccharin, but drank 2 ml of tap water from drinking cups presented in their home cages during preexposure sessions. These rats remained in their home cages throughout the experiment. Approximately 2 hr after the end of each preexposure session, the rats were allowed their normal 20-min access to tap water.

All the rats received a saccharin-illness pairing on Day 6. After they were weighed, the rats were allowed 10-min access to 2 ml of the saccharin solution from drinking cups presented in their home cages. At the end of this period, the drinking cups were removed from the cages and the rats were given 12 ml/kg ip injections of .15M LiCl. They were then returned to their home cages, and allowed 20-min access to tap water 2 hr later. Day 7 was a water recovery day. As before, the rats received 20-min access to tap water in their home cages 2 hr after weighing. This time, however, the rats were given simultaneous access to two tubes of tap water presented at the front of their home cages. The positions of the tubes were reversed halfway through the drinking period. On Day 8, the rats received a 20-min two-bottle preference test between saccharin and tap water in their home cages.

The location at which saccharin was initially presented was counter-balanced within groups, and the positions of the tubes were reversed halfway through the test. At the end of the test, each rat's consumption of saccharin and tap water was measured to the nearest .5 ml.

Data analysis. The data from this and all subsequent experiments were analyzed using the procedures described by Rodger (1967, 1974). In this procedure, analysis of variance and orthogonal post hoc contrasts are calculated in the manner proposed by Scheffé (1959). The obtained variance ratios are then evaluated against a new criterion, $\underline{F} [E\alpha]; v_1, v_2$ (Rodger, 1975), which yields a decision-based error rate of the first kind $E\alpha$. The use of this procedure ensures that the rate of erroneous decisions will not exceed the $E\alpha$ chosen by the experimenter when all null contrasts are true. In these experiments, values of $\underline{F} [E\alpha]$ were chosen which fixed Type I error rate at .05.

Results

Examination of the drinking cups at the end of each session revealed that little if any fluid was lost through spillage, and that no rat failed to consume all the fluid available to ~~it~~ during preexposure and conditioning sessions.

Before discussing the results of the saccharin aversion test, two general features of the data are worth commenting on, as a similar pattern of data emerged in all of the experiments to be reported. The first of these was that fluid access 2 hr prior to the daily watering seemed to decrease the rats' consumption of tap water, at least during the early portion of the preexposure phase. Although statistically reliable, the effect was a small one, and dissipated over the course

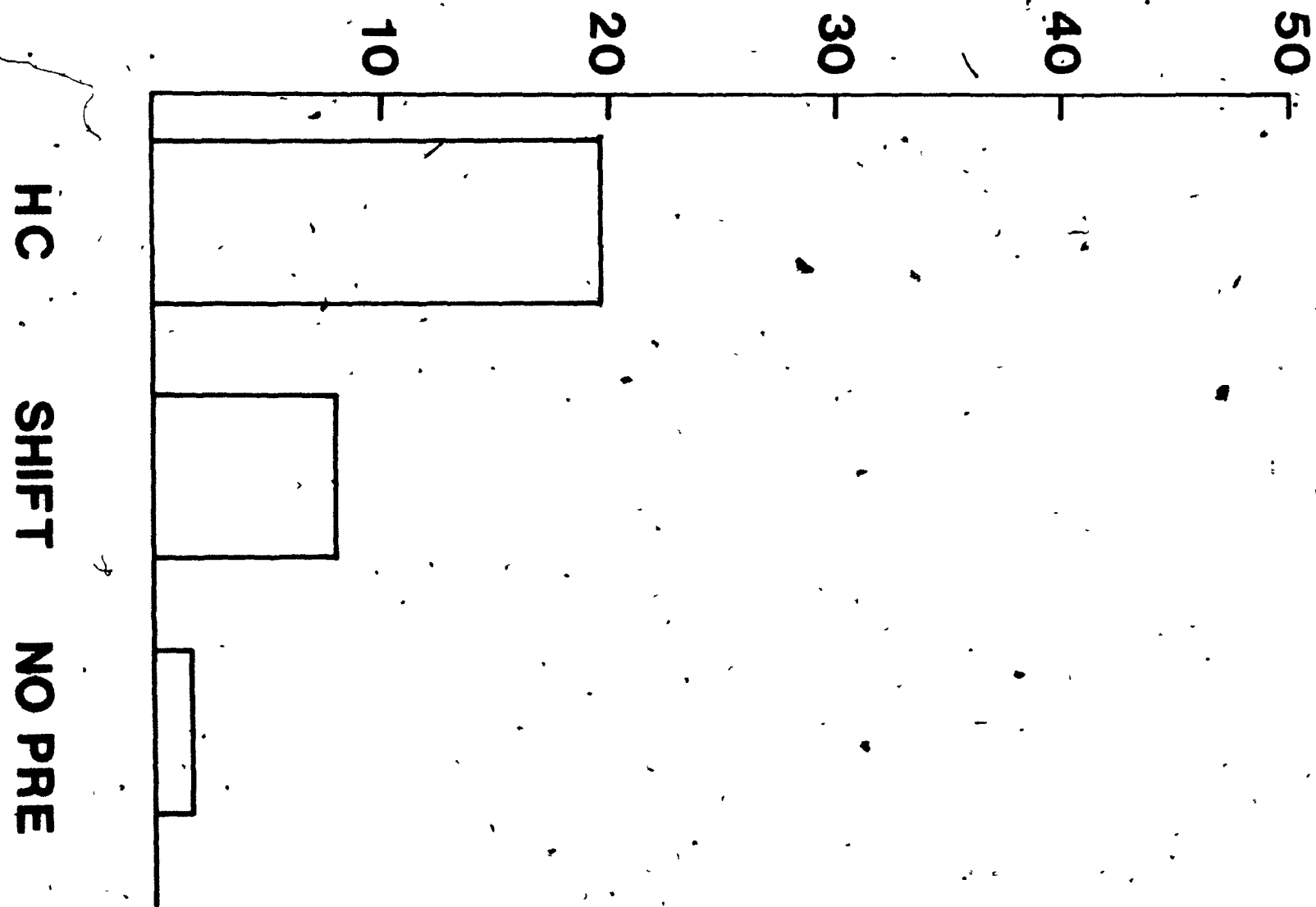
of the preexposure phase. By the end of this phase, the rats were again consuming tap water at baseline levels of consumption. The effect was not due to the novelty of the saccharin solution to which some of the animals were exposed. The effect was also apparent in the control rats which drank tap water during the preexposure sessions, and there were no significant between-groups differences in tap water consumption during this phase of the experiment.

A second finding which was also replicated in all the experiments to be reported was that the rats consumed less tap water on the day of the conditioning trial than they had on the previous day. Poisoning the rats 2 hr prior to fluid access thus suppressed their consumption of familiar tap water. The effect was significant in all cases, and represented an average decrease of 4-5 ml from intake on the preceding day. As before, the effect did not seem to be related to the preconditioning history of the various groups, as there were no significant between-groups differences in fluid consumption on the day of the conditioning trial. The rats' water consumption returned to baseline levels by the next day, and the groups did not differ in their water consumption on the recovery day.

There were no significant differences among the groups in total fluid consumption on the two-bottle test. Figure 1 presents each group's mean saccharin preference from the two-bottle test conducted in their home cages. These data were obtained by converting each rat's saccharin consumption to a percentage of its total fluid intake on the two-bottle test. A figure above 50% indicates that saccharin was preferred relative to tap water, whereas a figure less than 50%

Figure 1. Mean percentage saccharin preference for each group from the two-bottle test administered in Experiment 1.

MEAN % SACCHARIN PREFERENCE



indicates an aversion to saccharin relative to tap water.

Inspection of the graph reveals that all three groups acquired a strong aversion to saccharin after it was paired with LiCl. Preexposure to the saccharin solution appeared to reduce the magnitude of the saccharin aversion, as Groups Shift and HC avoided the solution somewhat less than the rats in Group No Pre. It also appears that changing the location of the preexposed saccharin solution between preexposure and conditioning attenuated the flavor preexposure effect; the rats in Group Shift avoided the saccharin solution to a greater extent than the rats in Group HC. Statistical analysis confirmed this impression of between-groups differences [$F(2,27)=6.58$]. Post hoc contrasts across the sample means indicated that the rats in Group Shift acquired a stronger saccharin aversion than those in Group HC [$F(2,27)=3.84$]. Given that the true size of the effect for the second contrast is at least as large as that for the first (Rodger, 1974, eqn. 8), this set of decisions implies that the groups can be ordered with respect to strength of saccharin aversion as follows: Group HC < Group Shift < Group No Pre.

Discussion

In this experiment, rats preexposed to a saccharin solution in their home cages and conditioned to avoid that taste there formed weaker saccharin aversions than rats who had never been exposed to saccharin. Preexposure to a flavor CS retarded later aversion conditioning of that flavor. Rats exposed to a saccharin solution in a novel environment and conditioned in their home cages, however, formed stronger saccharin aversions than rats both preexposed and conditioned in their home cages. Conditioning a preexposed flavor CS in an envi-

ronment other than the one in which it was exposed attenuated the normally detrimental effects of flavor preexposure on conditioning. This context shift manipulation did not abolish the flavor preexposure effect, however. Rats preexposed and conditioned in different environments still formed somewhat weaker aversions than no-preexposure controls.

It appears that environmental context is an important determinant of the flavor preexposure effect in aversion learning. A cross-context shift can disrupt the effects of stimulus exposure on learning, whether the preexposed stimulus is a flavor or an exteroceptive cue. This fact suggests that the processes which underlie flavor preexposure effects in aversion learning are the same as those which mediate preexposure effects in more traditional paradigms. As such, it would seem more appropriate to regard the flavor preexposure effect in aversion learning as another instance of latent inhibition than as a separate and different phenomenon.

That the context shift manipulation employed in this experiment did not completely abolish the flavor preexposure effect is not especially damaging to this conclusion. Although a context shift manipulation has sometimes been reported to facilitate later learning involving the preexposed stimulus (e.g., Lubow *et al.*, 1976), that outcome may not be an inevitable one (Anderson *et al.*, 1969). In addition, the context shift manipulation employed in this experiment involved a shift to a familiar environment, whereas animals were trained in a novel environment in those cases where facilitation of learning has been observed. There are a number of procedural differ-

ences, then, between this study and those which have reported facilitated learning following stimulus preexposure. This issue of facilitated learning following stimulus exposure is a complex one, and will be discussed further after the other experiments have been reported.

It should be noted that the disruption of the flavor preexposure effect produced by the context shift in this experiment was not especially large. This is not too surprising, given the small magnitude of the preexposure effect obtained in those rats who were preexposed and conditioned in their home cages. To some extent, the small preexposure effect obtained in this experiment can be attributed to the way in which the rats were preexposed to saccharin. In most flavor preexposure experiments, the subjects are allowed free access to the preexposure solution during preexposure sessions. In this experiment, however, the rats were allowed only limited access to the saccharin solution during exposure sessions. Munroe and Barker (1979) conducted a flavor aversion study which suggests that the small magnitude of the preexposure effect obtained in this experiment is due to the rats' limited access to saccharin during the exposure phase. In their study, rats were given repeated pairings of a small amount of saccharin (1 ml) with a weak illness reinforcer (1 ml of LiCl). In contrast to the finding of one-trial learning usually obtained in flavor aversion studies, they found that several pairings of saccharin with LiCl were required to condition a reliable aversion to saccharin under these conditions.

Experiment 2

Given the small magnitude of the preexposure effect obtained in

the first experiment, the conclusions of that experiment concerning the importance of environmental context for the flavor preexposure effect must be viewed with caution. This second experiment was designed to provide further evidence on the role of environmental context in the flavor preexposure effect. Essentially a replication of the first experiment, this study examined the effects of a cross-context shift on the flavor preexposure effect under conditions which should produce a somewhat larger preexposure effect.

Two parameters which are known to affect the magnitude of the flavor preexposure effect are the duration of the animal's exposure to the flavor (Domjan, 1972) and the number of times the animal is exposed to the flavor prior to conditioning (Elkins, 1973). Typically, increases in the values of these parameters are associated with larger preexposure effects. In this experiment, both the amount of fluid available to rats during preexposure sessions and the number of preexposure sessions were increased in an attempt to increase the magnitude of the flavor preexposure effect.

Method

Subjects. The subjects were 30 naive male hooded rats weighing 300-350 g prior to the start of the experiment. They were housed and maintained like those in Experiment 1.

Apparatus. The environments and drinking cups were the same as those used in Experiment 1.

Procedure. With only a few changes, the procedures and groups in this experiment replicated those of Experiment 1. First, the duration of the preexposure phase was increased from 5 to 8 days in this experi-

ment, with rats in each group given a preexposure session on each of those days. As before, the rats in Groups Shift and HC were preexposed to saccharin during these sessions, whereas those in Group No Pre received tap water to drink. Second, the amount of fluid available to the rats during a session was increased by 1 ml, so that the rats drank either 3 ml of saccharin or tap water during preexposure sessions. Finally, the rats in this experiment received a 20-min two-bottle preference test on each of two consecutive days, rather than the single test administered in Experiment 1.

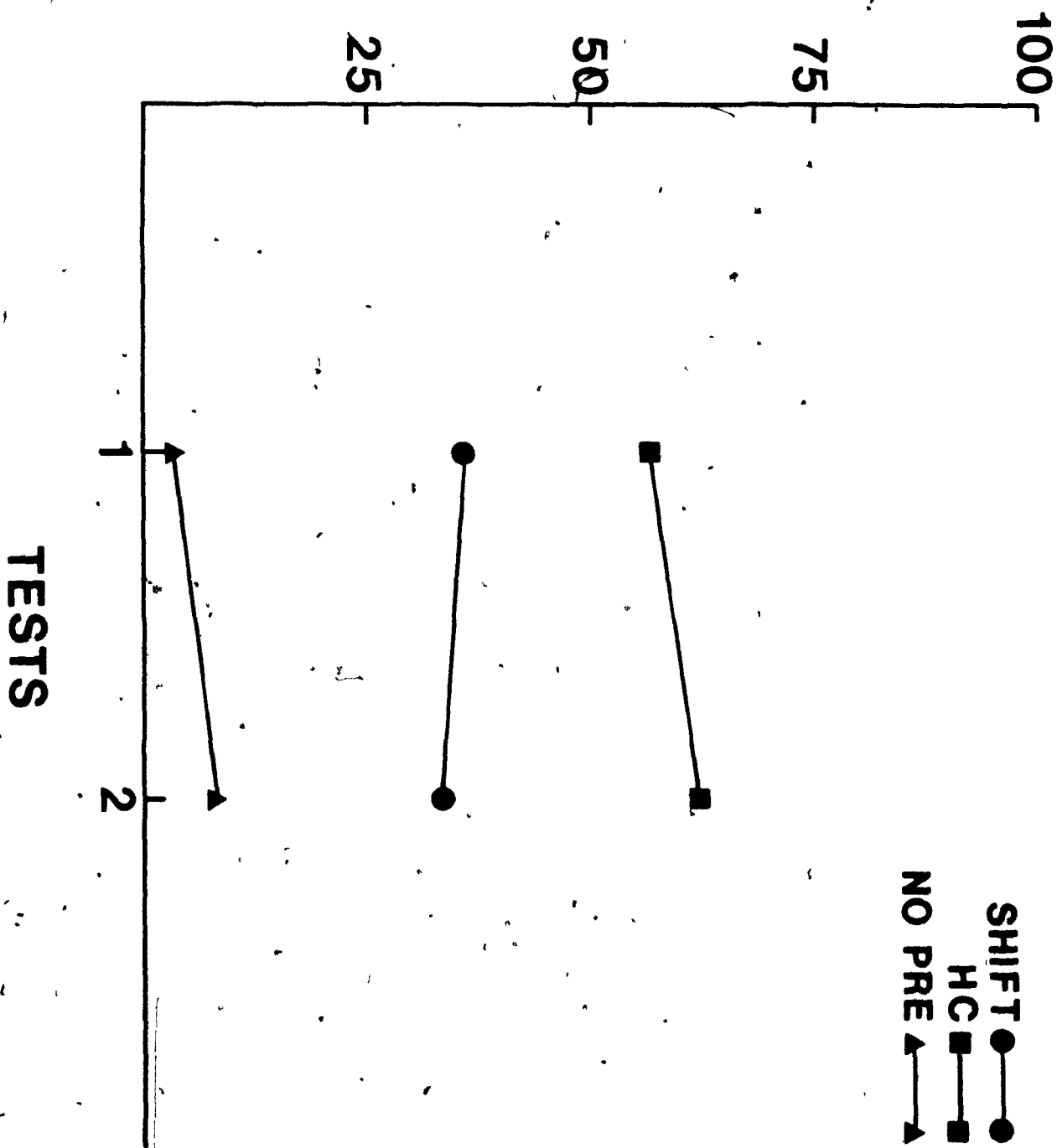
Results

Examination of the drinking cups at the end of each session showed that no fluid was being lost through spillage. In this experiment, no rat failed to completely consume all the fluid available to it during preexposure and conditioning sessions.

Analysis of fluid consumption on each of the two-bottle tests revealed that the groups did not differ in total fluid consumption. Figure 2 presents each group's mean saccharin preference from each of the test sessions. The first thing to note about these data is that the preexposure effect obtained in this experiment was substantially larger than that obtained in Experiment 1. In that experiment, the rats in Group HC (rats preexposed and conditioned in their home cages) showed a strong aversion to the preexposed saccharin solution after it was paired with illness. In this experiment, however, the rats in that group actually showed a slight preference for saccharin after it was paired with illness. Increasing the rats' preconditioning experience with saccharin by increasing the number of preexposure sessions

Figure 2. Mean percentage saccharin preference for each group from the two-bottle tests administered in Experiment 2.

MEAN % SACCHARIN PREFERENCE



and the amount of fluid available in those sessions thus produced a larger flavor preexposure effect.

Aside from the larger exposure effect obtained in this experiment, the pattern of results is similar to that of Experiment 1. Once again, the rats who were exposed to saccharin prior to conditioning (Groups Shift and HC) formed weaker saccharin aversions than the no-preexposure controls. It's also apparent, however, that the two groups preexposed to saccharin did not develop aversions of equal magnitude. The rats in Group Shift developed a stronger aversion to saccharin than the rats in Group HC. Analysis of the groups' mean saccharin preferences collapsed over the two test trials revealed significant between-groups differences [$F(2,27)=30.47$]. Contrasts across these means indicated that the rats in Group Shift formed a stronger saccharin aversion than those in Group HC [$F(2,27)=5.84$], but that these two groups combined formed a weaker aversion than the no-preexposure control group [$F(2,27)=24.62$]. Given that the true size of the effect for the second contrast is at least as large as that for the first (Rodger, 1974, eqn. 8), this set of decisions implies that the groups can be ordered with respect to strength of saccharin aversion as follows: Group HC < Group Shift < Group No Pre.

Discussion

In the first experiment, conditioning a preexposed saccharin CS in an environment other than the one in which it was preexposed attenuated the normally detrimental effects of flavor preexposure on learning. Those data suggested that environmental context plays an important role in mediating the effects of flavor preexposure on learning, and that the processes underlying flavor preexposure effects are the same as those mediating stimulus exposure effects in more traditional paradigms.

The generally small magnitude of the preexposure effect obtained in that experiment, however, precluded any firm conclusions regarding these points.

The results of this experiment put those conclusions on somewhat firmer ground. In this experiment, rats received more extensive pre-conditioning exposure to saccharin than in the first experiment, and a larger preexposure effect was obtained. Nevertheless, the same pattern of results was observed in the two experiments. As before, rats pre-exposed to saccharin in a novel environment and conditioned in their home cages formed stronger saccharin aversions than rats both preexposed and conditioned in their home cages. The data thus replicate those of the first experiment in showing that a context shift can disrupt the effects of flavor preexposure on learning. As in the first experiment, however, the context shift manipulation did not abolish the flavor preexposure effect. Rats preexposed and conditioned in different environments still formed somewhat weaker aversions than rats who hadn't been exposed to saccharin prior to conditioning. The similarity of the results of these two experiments suggests that the small disruptive effects of a context shift in the first experiment were due to the small magnitude of the preexposure effect obtained in that experiment, and not to the ineffectiveness of the context shift manipulation.

Taken together, the results of these two experiments indicate that environmental context is an important determinant of the effects of flavor preexposure on conditioning. Insofar as this is the case, it seems reasonable to conclude that the same processes mediate both flavor and other stimulus preexposure effects on learning. It should

thus be possible to use the flavor aversion paradigm to evaluate current accounts of latent inhibition. The next two experiments represent an initial attempt to evaluate one such account, the stimulus location hypothesis of Nadel and Willner (1980).

Experiment 3

Nadel and Willner (1980) suggested that stimulus exposure retards later learning because the preexposed stimulus is usually presented in the same location throughout preexposure and subsequent conditioning. They argued that the stimulus is novel when first exposed because it does not match what the animal's map predicts to be in the location where the stimulus is presented. With continued exposure, however, the animal's map is modified to reflect the occurrence of the stimulus in that place. The animal will now expect to find the stimulus in that location, and its occurrence there will be seen as a familiar event. Since familiarity retards learning, animals conditioned with the preexposed stimulus in its original location will learn about it more slowly than will animals not exposed to the stimulus prior to conditioning. This retardation of learning is not inevitable, however. Nadel and Willner predicted that changing the location of the preexposed stimulus would disrupt latent inhibition. The animal's map will identify the preexposed stimulus as a novel event when it occurs in a different location and its associability with other events will be restored. Cognitive map theory thus suggests that the effects of stimulus exposure on learning depend on where the preexposed stimulus is presented at the time of conditioning, as this will determine whether it is seen as novel or familiar.

The results of Experiments 1 and 2 are consistent with this analysis of latent inhibition. There, rats exposed to a saccharin CS in one environment and subsequently conditioned to avoid that flavor in a different environment formed stronger saccharin aversions than rats both preexposed and conditioned in the same environment. Conditioning the preexposed saccharin in a different environment disrupted latent inhibition. Insofar as these experiments demonstrate that latent inhibition depends on the continued presentation of the preexposed CS in the same environment, they can be considered support for a cognitive map interpretation of the phenomenon. These experiments do not directly address the role of stimulus location in latent inhibition, however. In asserting that an animal learns the location of an event, cognitive map theory implies that the animal should know not only in what environment that event occurs, but also where it occurs within that environment. Cognitive map theory thus predicts that simply changing the location of the preexposed stimulus within the preexposure environment should disrupt latent inhibition.

The present experiment examined the effects of a within-context shift on latent inhibition. Here, two groups of rats were initially exposed to saccharin from a particular location in an environment containing a number of distinctive objects. They were then poisoned after consuming saccharin in that environment. One group of rats was conditioned with saccharin in the location where it had previously been available to them in the preexposure environment. For the second group, the location of the saccharin solution relative to the other objects in the preexposure environment was changed just prior to the conditioning

trial. The rats were subsequently tested for saccharin aversion in their home cages. According to map theory, the rats preexposed and conditioned with saccharin in different locations should develop stronger saccharin aversions than the rats conditioned with saccharin in its original location within the preexposure environment. By comparing both groups of animals with appropriate no-preexposure controls it should also be possible to determine how effective a within-context shift is in disrupting latent inhibition.

Method

Subjects. The subjects were 30 naive male hooded rats weighing 250-300 g prior to the start of the experiment. They were housed and maintained under conditions like those in effect during the preceding experiments.

Apparatus. A total of 30 clear plastic environments with perforated metal tops were used as preexposure environments in this experiment. These environments measured 50 x 25 x 15 cm and were located on the floors of two dimly-lit rooms adjacent to the animal housing room. Each environment contained three wood blocks of different shapes and sizes (Block A=5 x 5 x 10 cm, Block B=7.5 x 7.5 x 2.5 cm, Block C=7.5 x 7.5 x 5 cm). These blocks were arranged to stand in a fixed relationship to one another and to the walls of the environment and were secured in place with a putty-like adhesive. Each environment also contained a single metal drinking cup, situated in one of two places relative to the blocks and walls of the environment. The location of the drinking cup within the preexposure environment could be changed between trials, but its location on any given trial was fixed by se-

curing it in place with the adhesive. A schematic drawing showing the locations occupied by the wood blocks and the drinking cup in the preexposure environment is presented in Figure 3.

Procedure. The rats were initially adapted to handling, water deprivation, and saline injections as described in the preceding experiments. They were then assigned to three groups ($n=10$) matched for fluid consumption over the last 5 days of the adaptation period.

Two groups of rats, Groups Same and Diff, were preexposed to saccharin on each of the next 8 days. After their daily weighing at 0930, the rats were removed from their home cages and placed in the preexposure environments for a 20-min period. There they were allowed to find and consume 3 ml of a .15% sodium saccharin solution from a drinking cup whose location in the preexposure environment remained constant from trial to trial. The rats were then returned to their home cages and the preexposure environments were cleaned. The rats in the third group, No Pre, were treated like those in Groups Same and Diff, except that they drank tap water in the preexposure environments instead of saccharin. Approximately 2 hr after the end of each preexposure session, the rats in all three groups were allowed their normal 20-min access to tap water in their home cages.

Special efforts were made during the preexposure phase to ensure that the rats' orientation and location on their release into the preexposure environment were varied from session to session. Similarly, the location of the drinking cup in the preexposure environment was counterbalanced within groups. Half the rats in each group were preexposed with the drinking cup in Location 1, whereas the remaining


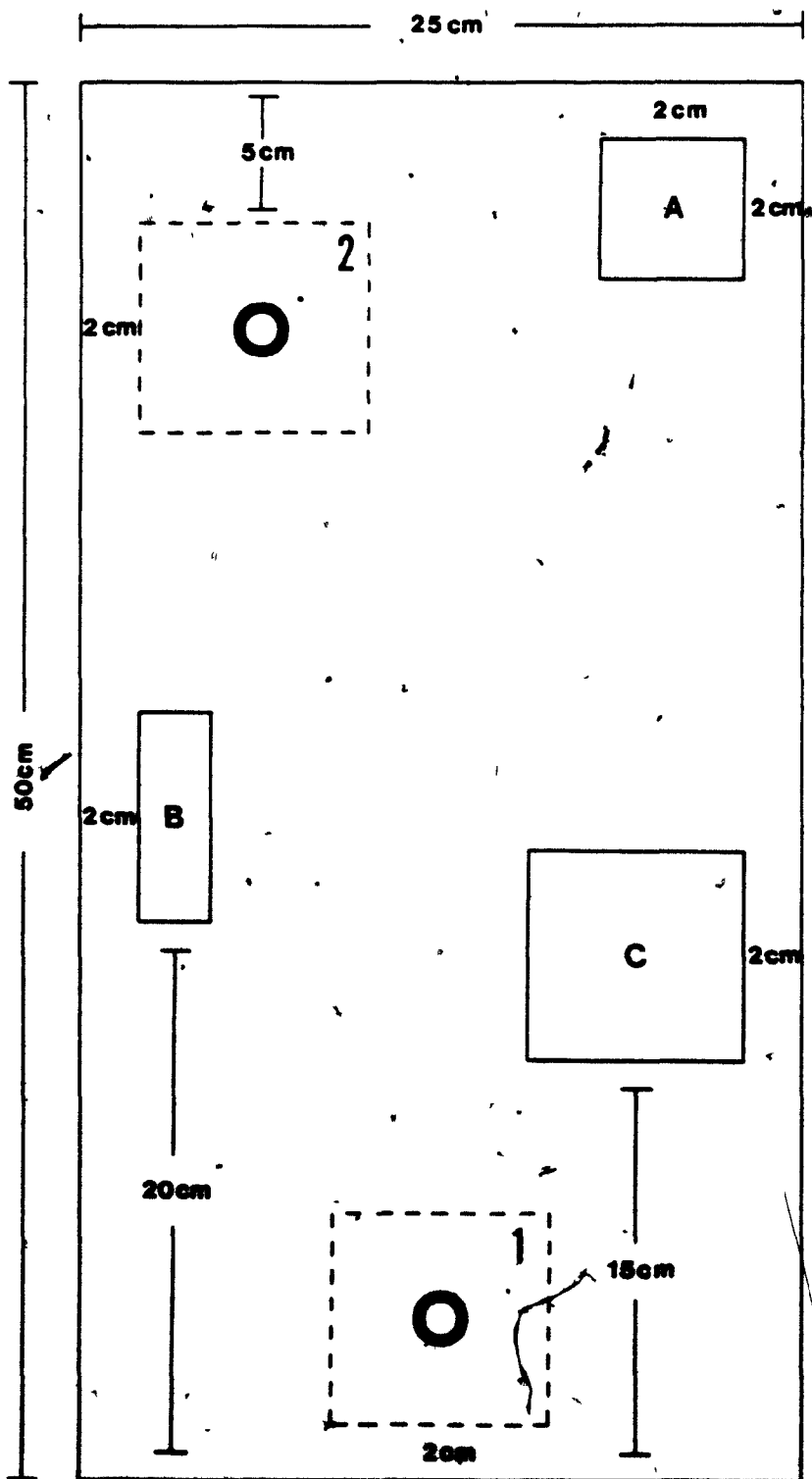


Figure 3. Scale floor plan of the preexposure environment used in Experiments 3 and 4. The areas labeled "A," "B," and "C" indicate the locations occupied by wood blocks. The dashed squares labeled "1" and "2" show the two possible locations for the drinking cup.



BLOCKS

A 5.0 x 5.0 x 10.0 cm

B 7.5 x 7.5 x 2.5 cm

C 7.5 x 7.5 x 5.0 cm

DRINKING CUPS

7.5 x 7.5 cm

rats in each group were preexposed with the drinking cup in Location 2.

The rats in all three groups received a saccharin-LiCl pairing on Day 9. After they were weighed, the rats were placed in the preexposure environments and allowed 10 min to consume 3 ml of the saccharin solution. For Groups Same and No Pre, the drinking cup, holding the saccharin solution was left in the location it had occupied during the preexposure phase. For the rats in Group Diff, the location of the drinking cup relative to the other objects in the preexposure environment was changed just prior to the conditioning trial. The rats were removed from the preexposure environments at the end of the 10-min period and injected with 12 ml/kg of .15M LiCl. They were then returned to their home cages, where they received their normal 20-min access to tap water 2 hr later.

Day 10 was a water recovery day. Approximately 2 hr after their weighing, the rats were allowed 20-min simultaneous access to tubes of tap water presented at the front of their home cages. The positions of the drinking tubes were reversed halfway through the fluid-access period. The rats were tested for saccharin aversion on Days 11 and 12. On these days, the rats received a 20-min two-bottle preference test between saccharin and tap water in their home cages. The location at which saccharin was initially presented in the home cage was counterbalanced both within groups and across tests, and the positions of the drinking tubes were reversed halfway through each test.

Results

Examination of the drinking cups at the end of each session in-

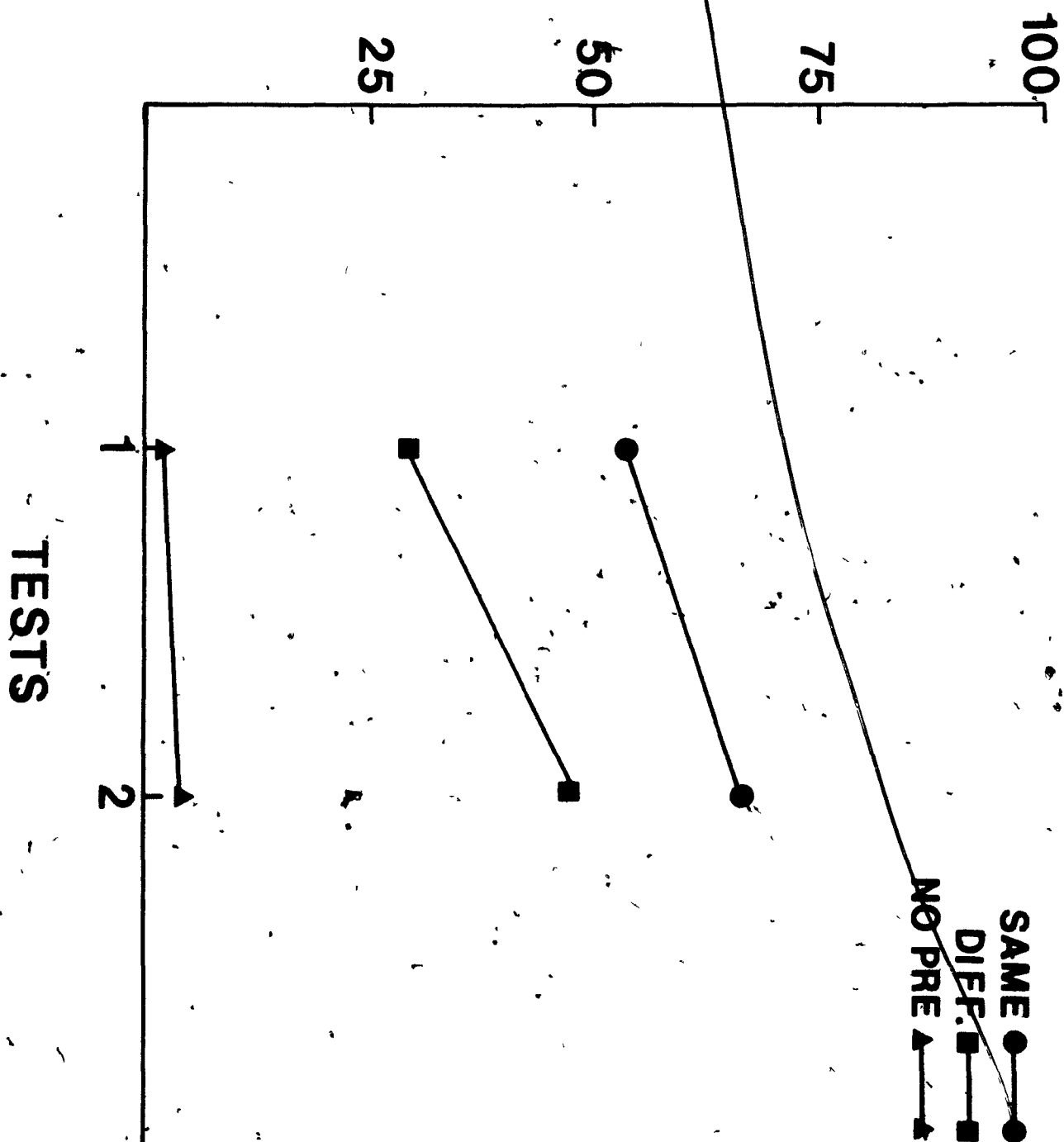
licated that no fluid was being lost through spillage. One rat from each of the three groups failed to consume all the fluid available to it during the first preexposure session. At no other time, however, did the rats fail to consume all the fluid available to them in the preexposure environments.

One rat from each of Groups Diff and No Pre broke its teeth in the home cage during the preexposure phase, and their data were excluded from all analyses. To maintain equal samples, the data from a randomly chosen rat in Group Same were also excluded from analysis.

Analysis of fluid consumption revealed that the groups did not differ in total fluid consumption during the two-bottle tests. Figure 4 presents each group's mean saccharin preference for each of the test sessions. Inspection of the figure reveals that the rats in Group No Pre displayed an almost complete avoidance of saccharin after its consumption was paired with illness. The rats in Groups Same and Diff, on the other hand, avoided the saccharin solution to a lesser extent than the rats in Group No Pre. Preconditioning exposure to saccharin attenuated the acquisition of an aversion to that flavor. However, it also appears that changing the location of the preexposed saccharin solution within the preexposure environment disrupted the detrimental effects of flavor preexposure on aversion conditioning. The rats in Group Diff displayed a greater reluctance to consume saccharin than did the rats in Group Same. Statistical analysis of each group's mean saccharin aversion over the two test trials confirmed this impression of between-groups differences in saccharin aversion [$F(2,24)=29.85$]. Post hoc contrasts across the group aver-

Figure 4. Mean percentage saccharin preference for each group from the two-bottle tests administered in Experiment 3.

MEAN % SACCHARIN PREFERENCE



ages indicated that Group Diff avoided the saccharin solution to a greater extent than did Group Same [$F(2,24)=4.40$], and that these two groups combined showed less avoidance of saccharin than did Group No Pre [$F(2,24)=25.45$]. Given that the true size of the effect for the second contrast is at least as large as that for the first (Rodger, 1974, eqn. 8), this set of decisions implies that the groups can be ordered with respect to strength of saccharin aversion as follows: Group Same < Group Diff < Group No Pre.

Discussion

The results of the present experiment suggest an important role for stimulus location in latent inhibition. Here, saccharin preexposure retarded the acquisition of an aversion to that flavor in rats conditioned with saccharin in the location where it was originally preexposed. This retardation of learning was greatly attenuated, however, if the spatial relations between the preexposed saccharin CS and the other objects in the preexposure environment were altered just prior to the conditioning trial. Changing the location of the saccharin solution within the preexposure environment disrupted latent inhibition for that flavor.

These findings support a cognitive map interpretation of latent inhibition. A basic tenet of the theory is that the novelty/familiarity of an event depends on its location. According to this view, an event is familiar if it matches what the animal's map predicts to be in the location where the event occurs; otherwise it is novel. Since novel and familiar events are differentially effective in learning tasks, the effects of stimulus exposure on learning should depend on the location of the preexposed stimulus at the time of conditioning. Preexposure should retard learning if the preexposed stimulus is pre-

sented in its original location, as the stimulus will be identified as a familiar event. Conditioning the animal with the preexposed stimulus in a different location should disrupt latent inhibition, however, as the preexposed stimulus will be seen as a novel event under these conditions. Cognitive map theory explicitly predicts a reduction in latent inhibition following a change in the location of the preexposed stimulus.

Environmental context also plays an important role in the accounts of latent inhibition developed by Lubow et al. (1976) and by Wagner (1978). As such, the results of this experiment would seem relevant to evaluating these accounts of latent inhibition. Lubow et al. argued that an adequate explanation of latent inhibition must take into account the preexposure history of the environment where training occurs. According to Lubow and his co-workers, the most effective conditions for learning are those in which there exists a contrast between the novelty of a stimulus and the novelty of the environment in which it is presented. Presumably, a condition of contrasting novelty of stimulus to environment results in the stimulus having a high "saliency," while the lack of such a contrast produces a stimulus of low saliency. This view implies that stimulus exposure should retard learning only when conditioning takes place in a familiar environment. Under these conditions, the stimulus will be of low saliency for preexposed animals (old stimulus in old environment), but will be highly salient for non-preexposed controls (new stimulus in old environment). Stimulus exposure should actually facilitate learning if training takes place in a novel environment. Here, the stimulus will be more salient for preex-

posed animals (old stimulus in new environment) than it is for non-preexposed controls (new stimulus in new environment). Whether stimulus exposure retards or facilitates learning, then, depends on the novelty of the training environment.

The results of the present experiment challenge a stimulus contrast account of latent inhibition. Lubow et al. define the contrast of stimulus to environment in terms of the difference in their absolute novelty. Changing the location of a stimulus within an environment should thus have no effect on its salience in that environment. As a result, stimulus contrast theory would have to predict no disruption of latent inhibition following a change in the location of the preexposed stimulus within the preexposure environment. The fact that this manipulation does attenuate latent inhibition argues against this approach to latent inhibition.

Wagner (1978, 1979) suggested that stimulus exposure retards learning because conditioning of the preexposed stimulus usually takes place in the preexposure environment. According to Wagner, the occurrence of an event engages the processes necessary for learning (e.g., rehearsal) only to the extent that the event is not already represented in short-term memory. With respect to latent inhibition, he argued that the repeated presentation of a stimulus in an environment leads to the formation of associations between the preexposed stimulus and the cues comprising the preexposure environment. When training subsequently takes place in that environment, these contextual cues "prime" a representation of the preexposed stimulus into short-term memory. The stimulus will then receive diminished processing and learning will

be retarded. The obvious implication of this view is that preexposure should retard learning only when training takes place in the preexposure environment. The theory predicts that the preexposed stimulus would be fully processed if training occurred in a different environment, as the contextual cues which would otherwise serve to prime the stimulus into memory would be absent. Environmental context influences latent inhibition, then, by determining whether the preexposed stimulus is primed into memory at the time of conditioning.

The results of the present experiment create difficulties for the information processing view insofar as they demonstrate that simple associations between contextual "cues" and the preexposed stimulus are insufficient to explain latent inhibition. As it stands, the theory would predict little or no reduction in latent inhibition following a within-context change in the location of the preexposed stimulus.

Changing the location of the preexposed stimulus within the preexposure environment does not alter the fact that conditioning takes place in the presence of the contextual cues previously associated with the occurrence of that stimulus. The preexposed stimulus should still be primed into short-term memory at the time of conditioning and learning should still be retarded. In order for the theory to accommodate results like those obtained in the present experiment, it would seem necessary to assume that the animal also learns about the spatial relations between the preexposed stimulus and the other objects in the preexposure environment. The most obvious possibility here is that the preexposed stimulus is represented in terms of its location within the preexposure environment. If this was the case, a reduction

in latent inhibition following a change in the location of the preexposed stimulus would make good sense. Presented in a different location, the preexposed stimulus would not match the representation of the stimulus already primed into short-term memory. The stimulus would be fully processed and learning would not be retarded.

Even though the information processing view can be modified to account for the results of within-context shift experiments, cognitive map theory would seem to provide a more adequate account of latent inhibition. Given that it is necessary to assume that animals learn about the spatial relations among events, it would seem unnecessary to postulate associations between contextual cues and the preexposed stimulus to account for latent inhibition. Wagner assumed that such associations were responsible for the effect on the basis of his finding (Wagner, 1979) that latent inhibition could be "extinguished" by giving animals context-alone sessions between preexposure and conditioning. It should be recognized, however, that cognitive map theory would also predict a reduction in latent inhibition following context-alone sessions. Such sessions should cause the animal's map of the preexposure environment to be revised to indicate that the preexposed stimulus no longer occurs there. The fact that latent inhibition can be extinguished, then, is compatible with both the cognitive map and information processing accounts of the effect. Insofar as cognitive map theory only assumes that animals learn about the spatial relations among events, it is more parsimonious than the information processing account of latent inhibition.

Experiment 4

Experiment 3 demonstrated that the location of the preexposed stimulus is an important factor in latent inhibition. There, changing the location of a preexposed saccharin CS attenuated latent inhibition for that flavor. The purpose of the present experiment was to replicate and extend this finding. In Experiment 3, the location of the saccharin CS was changed by altering its position relative to the other objects in the preexposure environment. This is not the only way to change the location of an event, however. To the extent that the location of an event is defined by its spatial relations with other objects, rearranging those objects will also change the location of that event. This suggests that it should be possible to disrupt latent inhibition simply by rearranging the cues used by the animal to define the location of the preexposed CS.

The present experiment was designed to test this possibility. Here, rats were forced to rely on the relations among intra-apparatus cues to define the location of a preexposed saccharin CS. Three groups of rats replicated the essential conditions of Experiment 3; one group was conditioned with saccharin in its original location, another was conditioned with saccharin in a new location in the preexposure environment, whereas the remaining group was not preexposed to saccharin prior to conditioning. The rats in a fourth group were also preexposed to saccharin prior to conditioning. For the rats in this group, the cues in the preexposure environment were rearranged just prior to the conditioning trial. If stimulus location is important in latent inhibition, these rats should display reduced latent inhibition for the

saccharin CS. Furthermore, these rats should display saccharin aversions of approximately the same magnitude as those displayed by rats actually suffering a change in the position of the saccharin CS.

A second purpose of this experiment was to examine the effects of removing individual cues from the preexposure environment on latent inhibition. O'Keefe and Nadel (1978) argued that the spatial relations which define the location of an event are redundant in the sense that no single relation is necessary to define the location of that event. The removal of any given cue from an environment does not alter the spatial relations which exist between the remaining cues and the reference event. So long as some minimal number of cues remain in their original positions relative to the reference event, the event should be seen as occurring in the same location. As applied to latent inhibition, this view suggests that the removal of any given cue from the preexposure environment will have relatively little effect on latent inhibition for the preexposed stimulus. Three additional groups of rats were preexposed to saccharin in the present experiment to test this possibility. For each of these groups, one of the wood blocks was removed from the preexposure environment just prior to the conditioning trial. If the spatial relations which define the location of an event are truly redundant, rats in these cue-deletion groups should display little or no reduction in latent inhibition for the preexposed saccharin CS.

Method

Subjects. The subjects were 56 naive male hooded rats weighing 250-300 g prior to the start of the experiment. They were housed and

maintained under conditions like those in effect during the preceding experiments.

Apparatus. The preexposure environments were the same as those used in Experiment 3, except that the outer walls and floors of the environments were covered with aluminum foil to minimize visual input from extra-apparatus cues.

Procedure. The rats were initially adapted to handling, water deprivation, and saline injections as described in the previous experiments. They were then assigned to seven groups (n=8) matched for average water consumption over the last 5 days of the adaptation period.

The rats in Groups Same, Diff, and No Pre were preexposed and conditioned as described in Experiment 3. The rats in Groups Same and Diff were preexposed to saccharin on eight occasions prior to conditioning, whereas the rats in Group No Pre only drank tap water in the preexposure environment. On the conditioning trial, the rats in Group Same drank saccharin from the location where it was originally exposed, whereas the rats in Group Diff found saccharin in a different location in the preexposure environment. The rats in Group No Pre were conditioned with saccharin in the location where they had previously found tap water.

The four remaining groups were also preexposed to saccharin prior to conditioning. During the preexposure phase, the rats in these groups were treated exactly like the rats in Groups Same and Diff. The rats were then poisoned after drinking saccharin in the preexposure environment. For the rats in Group Exchange, the wood blocks in the preexposure environment were rearranged just prior to the con-

ditioning trial. This was done by systematically exchanging the blocks with one another in a counterclockwise fashion; block A was presented in the location originally occupied by block B, B was presented in C's original location, while C was presented in A's original location. Each of the three remaining groups had one of the wood blocks removed from the preexposure environment just prior to the conditioning trial. For the rats in Group Near, the block nearest the drinking cup (A or C) was removed, whereas the rats in Group Far had the block farthest from the drinking cup (A or C) removed prior to conditioning. Finally, the rats in Group Inter had the block intermediate to the drinking cup (B) removed from the preexposure environment.

The rats in all seven groups were tested for saccharin aversion as described in the preceding experiment. Following a water recovery day, the rats received a two-bottle preference test between saccharin and tap water in their home cages on each of 2 consecutive days.

Results

Examination of the drinking cups at the end of each session revealed that little or no fluid was being lost through spillage. One rat from each of Groups Same, No Pre, and Far failed to consume all the fluid available to it during the first preexposure session. At no other time, however, did the rats fail to consume all the fluid available to them in the preexposure environment.

Analysis of fluid consumption revealed that the groups did not differ in total fluid consumption on either of the two-bottle tests. Table 1 presents each group's mean saccharin preference for each of the test sessions. The first thing to note about the data is that

Table 1
Mean Percentage Saccharin Preferences from the
Two-bottle Tests in Experiment 4

Group	Test	
	1	2
Same	55.3	78.0
Diff	35.4	63.5
No Pre	2.6	5.5
Exchange	41.8	70.6
Near	53.5	81.3
Far	44.3	72.6
Inter	64.8	71.3
Remove A ^a	43.1	78.1
Remove B ^a	64.8	71.3
Remove C ^a	54.7	75.8

^aRecalculated data from Groups Near, Far, and Inter

all the groups preexposed to saccharin prior to conditioning acquired weaker saccharin aversions than Group No Pre. Saccharin preexposure retarded the acquisition of an aversion to that flavor. It's clear, however, that the rats preexposed to saccharin did not all acquire saccharin aversions of the same magnitude. The weakest saccharin aversions were displayed by Groups Same, Near, and Inter, whereas Groups Diff, Exchange, and Far all displayed stronger aversions to saccharin. The differences between these two sets of groups were most apparent on the first day of testing and had largely disappeared by the time of the second test.

Analysis of variance on the data from the first test session confirmed the existence of between-groups differences [$F(6,49)=7.78$]. Contrasts across the group averages indicated that Groups Same, Near, and Inter did not differ from one another. Likewise, the differences among Groups Diff, Exchange, and Far were not significant. These latter groups did acquire stronger saccharin aversions than the former set of groups, however, [$F(6,49)=1.45$]. Finally, all the groups preexposed to saccharin acquired weaker aversions than the rats in Group No Pre [$F(6,49)=5.95$]. Given that the true size of the effect for the second contrast is at least as large as that for the first (Rodger, 1974, eqn. 8), this set of decisions implies that the groups can be ordered with respect to strength of saccharin aversion as follows: Group Same = Group Inter = Group Near < Group Diff = Group Exchange = Group Far < Group No pre. Analysis of the data from the second test session indicated that there were no differences among the groups preexposed to saccharin. These groups continued to display weaker saccharin aversions than Group No Pre, however.

The data from the cue-deletion groups can also be analyzed in terms of the specific block removed from the preexposure environment. The lower portion of Table 1 presents recalculated data from these groups which show the effects of removing a particular cue from the preexposure environment, regardless of its distance from the drinking cup. It's apparent from these data that the rats who had block A removed from the preexposure environment acquired stronger saccharin aversions than rats who had either blocks B or C removed from the preexposure environment prior to conditioning. Re-analysis of the data from the first test session confirmed this impression [$F(6,49)=7.93$]. Post hoc contrasts across the group averages indicated that Groups Same, Remove B, and Remove C did not differ from one another, nor did Groups Diff, Exchange, and Remove A. This latter set of groups displayed stronger saccharin aversions than the former set of groups [$F(6,49)=1.60$]. All these groups displayed weaker saccharin aversions than Group No Pre [$F(6,49)=6.00$]. Given that the true size of the effect for the second contrast is at least as large as that for the first (Rodger, 1974, eqn. 8), this set of decisions implies that the groups can be ordered with respect to strength of saccharin aversion as follows: Group Same = Group Remove B = Group Remove C < Group Diff = Group Exchange = Group Remove A < Group No Pre.

Discussion

Cognitive map theory predicts that the effects of stimulus exposure on learning will depend on where the stimulus is located at the time of conditioning. The animal's map will identify the stimulus as a familiar event if it is presented in its original location, and learning should be retarded. The preexposed stimulus will be seen as a novel event if it is presented in a different location, however.

and learning should not be retarded under these conditions. Experiment 3 provided some initial support for this view. There, changing the location of a preexposed saccharin CS by altering its position in the preexposure environment attenuated latent inhibition for that flavor. The present experiment replicated this finding and provided a further demonstration of the effect. Here, changing the location of the saccharin CS by rearranging the cues in the preexposure environment also attenuated latent inhibition for that flavor. Furthermore, changing the location of the saccharin CS in this way was just as effective in attenuating latent inhibition as actually altering its position in the preexposure environment. Insofar as these findings reinforce the view that stimulus location is important in latent inhibition, they provide further support for a cognitive map account of the effect.

The data from the cue-deletion groups run in this experiment are more difficult to interpret. There are two major problems here. It is clear that one of the three blocks in the preexposure environment was more important than the others, as removal of this cue attenuated latent inhibition for the preexposed saccharin CS. Unfortunately, it's not clear whether the significant cue in this situation was the block farthest from the drinking cup (block A or C) or a particular block (block A). The data are compatible with either view. The problem is compounded by the fact that it is unlikely that it was the mere absence of the significant cue which disrupted latent inhibition. Given the performance of Groups Diff and Exchange in this experiment, it seems more likely that removal of this cue disrupted

latent inhibition because it altered the relationship which had previously existed between that cue and the other cues in the preexposure environment. The nature of this relationship remains unclear, however.

There is another problem in interpreting these data. The present experiment was only designed to determine whether removal of individual cues from the preexposure environment would affect latent inhibition. As such, it provides few insights into why this manipulation attenuated latent inhibition for the saccharin solution. The most obvious possibility is that removal of the significant cue caused the saccharin CS to be perceived as occurring in a new location. If this was the case, these data would contradict the view espoused by O'Keefe and Nadel (1978) that the spatial relations which define the location of an event are inherently redundant. There is also a second possibility. Both Lantz (1973) and Rudy *et al.* (1977) observed that presentation of novel stimulation just prior to conditioning would attenuate latent inhibition for a preexposed stimulus. This suggests that removal of the significant cue from the preexposure environment may have acted as a non-specific sensitizing influence to disrupt latent inhibition. At the present time, there is no basis for preferring one interpretation over another. In order to differentiate these alternatives, the task used in this experiment would have to be restructured to force the rats to use their knowledge of the spatial disposition of the environment to find the saccharin CS. Changes in latent inhibition could then be correlated with rats' performance on the place learning task. If cue deletion disrupts latent inhibition because it changes the location of the preexposed stimulus, performance on the place learning

task should also be disrupted. Place learning should not be impaired, however, if cue deletion affects latent inhibition via a process of sensitization.

General Discussion

The present series of experiments examined the effects of changing the location of a preexposed saccharin CS on aversion conditioning of that flavor. Here, various manipulations which changed the location of the saccharin CS were found to attenuate latent inhibition for that flavor. These included presenting the saccharin CS in a different environment (Experiments 1 and 2), altering its position in the preexposure environment (Experiments 3 and 4), and rearranging the cues in the pre-exposure environment (Experiment 4). In all cases, rats suffering a change in the location of the saccharin solution acquired stronger aversions than rats conditioned with saccharin in its original location. Changing the location of the saccharin CS did not completely abolish latent inhibition for that flavor, however. The results of these experiments indicate that the location of the preexposed stimulus is an important factor in latent inhibition. The manipulations employed in these experiments have little in common other than the fact that they all changed the location of the preexposed saccharin CS. This makes it rather unlikely that the disruption of latent inhibition observed in these experiments resulted from anything other than the change in the location of the preexposed stimulus.

The results of these experiments are directly relevant to the cognitive map account of latent inhibition. One implication of the

view that animals build cognitive maps is the idea that novelty is as much a relative property of an event as it is an absolute property of that event. O'Keefe and Nadel (1978) argued that an event is novel if it does not match what the animal's map predicts to be in the location where that event occurs. Conversely, a familiar event is one whose occurrence in a given location is already predicted by the animal's map of the environment. Since an animal is more likely to learn about a novel event than a familiar one, the location of an event should be an important determinant of what the animal will learn about that event. Nadel and Willner (1980) applied this idea to latent inhibition to suggest that stimulus exposure retards later learning because the preexposed stimulus is usually conditioned in the location where it was originally exposed. Under these conditions, the preexposed stimulus will be familiar and learning will be retarded. The preexposed stimulus would regain its novelty if it was presented in a different location, however, as the animal's map would not predict its occurrence in a new location. Cognitive map theory therefore predicts that changing the location of the preexposed stimulus will disrupt latent inhibition. Insofar as this prediction was confirmed in all four experiments reported here, these experiments support the cognitive map view that stimulus location is important in latent inhibition.

Although Nadel and Willner (1980) did not address themselves to the question of facilitated learning following stimulus exposure, cognitive map theory does provide a rationale for the results of such "perceptual learning" experiments. The Lubow et al. (1976) study

described earlier makes it clear that stimulus exposure facilitates learning only when training takes place in a novel environment.

Studies of exploration provide important clues as to why this is so.

Whereas animals approach a novel stimulus in preference to a familiar one when tested in a familiar environment, just the opposite is true in a novel environment. Sheldon (1969) demonstrated that rats preferred a familiar object to a novel one when they were tested in a novel environment. Similarly, Yamamoto *et al.* (1980) found that rats adopted a familiar object as a base from which to explore a novel environment. The simplest explanation for rats' attraction to pre-exposed stimuli in a novel environment is that of escape from fear. Novel environments certainly evoke curiosity and exploration, but they also tend to evoke fear. In such a situation, it is not surprising that an animal will approach objects like those it previously encountered in a different environment. Preexposed stimuli provide a means of reducing the fear elicited by the novel environment, if only because those stimuli were not associated with aversive events in the past.

These considerations suggest two ways in which stimulus exposure could act to facilitate learning when training takes place in a novel environment. Since the preexposed objects are the relevant discriminanda, the preexposed animal's tendency to approach those objects will rapidly bring it into contact with the relevant reinforcement contingencies. This is important insofar as most animals initially adopt place strategies in many discrimination learning tasks (cf. O'Keefe & Nadel, 1978, pp. 264-290). The preexposed animal may or may not adopt

a cue strategy from the outset of training, but its tendency to approach the preexposed objects will at least help it effect the transition from a place strategy to the cue strategy demanded by the task. The non-preexposed animal, on the other hand, has no such advantage.

A second possibility is that stimulus exposure facilitates learning because preexposed and non-preexposed animals differ in their unconditioned responding to the discriminative stimuli. At best, the discriminative stimuli will be neutral for the non-preexposed animal at the start of training. It's not unreasonable to think that the discriminative stimuli will have positive incentive value for the preexposed animal, however, as they are "safe" stimuli in an otherwise dangerous environment. These differences in initial affective response to the discriminative stimuli could result in preexposed animals mastering an appetitive task faster than non-preexposed animals. This concern is relevant here, as perceptual learning has only been demonstrated in appetitive tasks. Until perceptual learning is demonstrated in a task involving aversive motivation, this account of perceptual learning must be considered a viable one.

The foregoing indicates that ideas derived from an analysis of cognitive mapping can be fruitfully applied to understanding both latent inhibition and perceptual learning. The view that animals represent events in terms of their locations, however, has implications which extend beyond the analysis of stimulus exposure effects on learning. The most obvious of these is that the location of an event is a more important determinant of learning and performance than has previously been suspected. In what follows, the idea that

animals possess context-dependent (spatial) representations of events will be applied to the phenomenon of blocking and to some recent findings on extinction to illustrate how this idea may further our understanding of the effects seen in these situations.

Kamin (1969) reported that prior conditioning to an element A would attenuate conditioning to an element B when the stimuli were subsequently presented in an AB compound. Since then, the phenomenon of blocking has generated a great deal of research and almost as much speculation as to the basis for the effect. Blocking of the added stimulus has, at various times, been attributed to a reduction in reinforcer potency (e.g., Wagner, 1978) and to a reduction in CS potency (e.g., Mackintosh, 1978). Although there are crucial differences between these two approaches, they share the common assumption that blocking is due to the fact that the reinforcer is already fully predicted by the pretrained stimulus. Cognitive map theory is indifferent as to whether blocking is due to changes in reinforcer or CS potency. Instead, the theory focuses attention on what is being predicted by the preconditioned stimulus. According to this view, the animal in a blocking environment is learning to expect a particular reinforcer (a reinforcer in a specific location) as opposed to a general type of reinforcer. The theory therefore predicts that changing the location of the reinforcer at the start of compound conditioning should attenuate blocking of the added stimulus ("unblocking"). The theory also leads to an interesting prediction concerning the effects of interspersing element-alone refresher trials among the compound trials. Giving the animal trials on which the pretrained stimulus signals

the reinforcer in its original location should actually enhance unblocking on compound trials where the reinforcer occurs in a different location. These predictions have yet to be tested, but it's clear that the results of such a study would be of theoretical interest.

The idea that animals' expectations of events are referenced to the locations where those events occur also helps to make sense of some recent findings in the extinction literature. It now appears that extinction of conditioned responding to a stimulus is specific to the environment where extinction takes place. Bouton and Bolles (1979) gave rats tone-shock pairings in one environment and then extinguished fear of the tone in either the same environment or a different one. They found that rats given extinction trials in the training environment showed little fear of the tone when subsequently tested there. Rats extinguished in a different environment and tested in the training environment, on the other hand, evidenced as much fear of the tone as non-extinguished controls. Bouton and Bolles were able to rule out factors like pseudoconditioning, residual fear of the training context, and inhibitory conditioning of the extinction context as possible explanations for the renewal of fear effect they obtained. The fact that extinction is context-specific makes good sense when viewed from the perspective of cognitive map theory. The conditioned stimulus will be seen as a different event when it is presented in a different location. Even though the animal recognizes that the CS is a different event, its initial response to the CS will be dictated by its previous experience with that stimulus. The animal will therefore show conditioned responding to the CS upon its first

few presentations in a new location. The animal will quickly learn that the stimulus does not predict reinforcement, however, and will adjust its behavior accordingly. Cognitive map theory therefore predicts that extinction should be a relatively rapid affair following a change in the location of the conditioned stimulus, and this is indeed the case (Archer, Sjöden, Nilsson, & Carter, 1979). Since the CS is represented in terms of its location, extinction of the CS in a different location will not affect the association which was established between that stimulus and reinforcement in a different environment. The presentation of the CS in its original location should continue to evoke conditioned responding appropriate to the association between that stimulus and reinforcement.

It's clear from the above two examples that cognitive map theory can be applied to situations other than those of latent inhibition and perceptual learning. While we know some things about the properties of cognitive maps, there's a great deal more of which we are ignorant. We still know very little about the precise nature of the representations subserved by the spatial mapping system, i.e., how detailed are these representations? We also know relatively little about how animals actually define locations or how the information contained in maps is translated into performance. Finally, we need to know more about how the spatial mapping system interacts with non-spatial (i.e., context-independent) memory systems to control the ongoing behavior of the organism. All these questions are prominent candidates for future research. Even though we cannot provide detailed answers to any of these questions at the present time, this should not

prevent psychologists from recognizing the potential importance of spatial concerns for our understanding of animal learning and memory.

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