Cue use in state-dependent learning

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Four experiments were conducted to determine what cues rats used to escape from a water maze in the normal nondrugged state or while drugged with pentobarbital. The subjects were trained to escape from a water maze that either required or enabled them to use place or response cues. The results showed that drugged and nondrugged rats used different cues to escape from the maze; drugged rats learned response sequences, while nondrugged rats learned either the place of exit from the maze or response sequences. Although some rats selected and used different cues in different states, they showed impaired learning when they were required to use the same cue in both the normal and drugged states. Learning in the drugged state appeared to be different from learning in the normal state, in that drugged rats were restricted in their cue use. The implications of these findings for theories of state-dependent learning were discussed.

Bliss (1974) has summarized five different hypotheses which have been advanced to explain state-dependent learning. They are: (1) The structural hypothesis, advanced by Girder and Cullen (1937) and Girden (1940), which maintains that in the drugged state, the cortex is inhibited so that it does not inhibit the subcortex. Then, what the animal learned in the drugged state with uninhibited subcortical mechanisms was blocked subsequently, when the cortex again exerted inhibitory control as the drug wore off. (2) The complex mediating processes hypothesis, advanced by Overton (1964), which states that cell assemblies that mediate particular learned behaviors are altered by drugged states so that old pathways are disrupted and new ones are formed. Therefore, routing of the neural impulses that mediate behavior is over pathways that are unique to a particular drugged state. (3) The response initiation hypothesis, advanced by Bindra and his associates (Bindra, Nyman, & Wise, 1965; Bindra & Reichert, 1966, 1967), which contends that the connections formed between the conditioned stimulus and the movement-initiating mechanism are specific to the drugged state. When the drugged state is altered, the animal loses its ability to initiate movement because the connection is discontinued. (4) The simple-complex hypothesis, advanced by Sachs (1967), which argues that a drugged animal has impaired cognitive functioning and does not attend to many of the features of its environment. When the animal is not drugged, those features of the environment now elicit exploratory responses which compete with

the learned response. This response competition then produces what appears as dissociation. (5) The drug-stimulus hypothesis, advanced by Brown, Feldman, and Moore (1968), Otis (1964), and Overton (1972), which argues that the presence of a drug produces a physiological state which has stimulus characteristics that are on a continuum with the normal state. The stimulus characteristics of the drugged state can act as a discriminative stimulus and exert control over the response. Learning dissociation represents a failure of generalization of the stimulus characteristics of the drugged state to the normal state and, hence of the response, from one end of the drugged state portion of the stimulus curve to the normal nondrugged end of the curve.

After reviewing the evidence supporting each of these theories of state-dependent learning, Bliss concluded that there is no "unambiguous" explanation of the basic mechanism(s) involved in state-dependent learning. The present research was undertaken to provide data that might help to determine what a rat learns or can learn in a water maze, either while it is drugged with pentobarbital or while it is in the normal, nondrugged state. The basic strategy was to hold the state constant for some animals, but to change tasks so that the cues that are used to solve the task in a particular state can be identified. In other animals, the states were changed as the animals learned tasks and lack of interference of learning between tasks was taken as evidence of state-dependent learning. Still other animals were required to use particular cues in particular states, and differences in rates of learning were taken as evidence of ease or difficulty in using a particular cue in a particular state. The adequacy of the drug-stimulus hypothesis was tested. If the drugged state serves as a discriminative stimulus, and if failure of stimulus generalization of state characteristics is the basis for discrimination, the selection and use of maze cues by a rat to solve a problem should not be affected by the animal's drugged state.

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Furthermore, the particular types of cues that drugged animals selected to solve the maze problem, as compared to those selected by the nondrugged animals, would provide evidence relevant to the simple-complex hypothesis and other theories of state-dependent learning.

GENERAL METHOD

Subjects

Male rats of both Wistar and Long-Evans strains between 120 and 240 days old were used. They were individually housed with ad-lib access to food and water.

Apparatus

The apparatus used in all experiments was a water maze, constructed of ½-in. plywood that was waterproofed with fiberglass. The walls were 24 in. high, the alleyways were 4 in. wide, and each alley was 12 in. long. One outside portion of the maze, used as a warming, drying, and resting area, was illuminated by a heat lamp. Movable inserts were used so that various maze patterns could be arranged, and any alleyway could serve as either a starting or goal area. The particular maze patterns the animals learned for each of the following experiments are shown in the specific method sections for that experiment.

Procedure

The rats were given daily sessions of five corrective trials until they learned to escape from the 13°C water. Eight out of 10 errorless trials served as the training criterion. No training criterion was needed in Experiment 2 because the rats were permitted to select their escape route from a number of alternative routes. At the end of each trial, an animal was given 3 min in the warming area. Rats trained in the drugged state were given an IP injection of 25 mg/kg of sodium pentobarbital, and 30 to 40 min later, after the righting reflex returned, the daily training sessions were begun. To incorporate the features of both experimental designs used in investigations of state-dependent learning, both one-way and two-way training procedures were used. In two-way training, animals were trained in drugged and nondrugged states on successive days until they reached criterion in both states. If criterion was reached in one state before the other, the animals were given consecutive training sessions in the untrained state until criterion was also reached in that state, and then, before any testing took place, one 5-trial refresher session was given in the state in which training criterion was first achieved. The state of the first training session was counterbalanced within the two-way groups so that equal numbers of animals were first trained in drugged and nondrugged states. In the one-way training procedure, a retention test was not given in the alternate state, but from a different starting position in the maze in the same state. Thus, tasks, rather than states, were changed. In these experiments, we were not directly dealing with state-dependent dissociation or control, but rather with aspects of drug learning that have important consequences for theories of state-dependent learning. The control, to demonstrate state-dependent control of performance for the two-way animals, was the one-way training procedure, and vice versa. The learning rates of animals in each of two states of one-way training were compared to the learning rates for animals in the corresponding states in two-way training. If learning rates were comparable for corresponding drug and nondrug states, this was evidence of state-dependent control of performance.

EXPERIMENT 1

The first experiment determined whether rats used place or response cues to learn maze routes in drugged

and nondrugged states. This was done by training drugged or nondrugged rats to swim to a ladder to climb out of the water maze. After training criterion had been reached, the rats were tested by starting them in a different startbox, one that gave a mirror image of the maze arrangement used during training. If a rat had learned to go to the place of the ladder during training, it ignored the route used in training. Conversely, if a rat had learned a response sequence during training, when tested from the different startbox, it ignored the place of the ladder and executed its learned response sequence. Thus the testing in the rotated maze permitted the rats to exhibit whether they were responding to place or response cues. This paradigm is essentially the same as that used in the rotated T-maze experiments in the 40s and 50s (Restle, 1955).

A second objective of the experiment was to see if rats that learned the maze in both drugged and nondrugged states (two-way training) used different cues in the two states. Furthermore, the learning rates of one-way trained rats in the drugged state and the nondrugged state were compared with each other, as well as with the learning rates of two-way rats trained in the drugged and nondrugged states.

Subjects and Procedure

Forty-two Wistar and six Long-Evans male rats were used. They were assigned randomly to two groups of 24 animals. Each group was assigned to either the one-way or two-way procedure. Animals in the one-way training group were further divided into two equal-sized groups that were trained in either the drugged or in the nondrugged state. An equal number of rats in each training group was trained to use each of four routes shown in Figure 1.

When the one-way rats reached the escape criterion of 8 out of 10 errorless trials, they were given three test trials in their training state from the mirror-image startbox, and their escape routes were recorded. The two-way rats were trained in one startbox, e.g., S_1 in Figure 1, in one state and in the other startbox, e.g., S_2 in Figure 1, in the other state. When they reached criterion in both drugged and nondrugged states, they were also given three test trials in their training state from the

Figure 1. The maze arrangement used in Experiment 1. The startboxes are designated S_1 and S_2 , and the four goal areas, G_2 , G_3 , G_6 , and G_7 . The training routes are indicated by the broken, arrowed lines.

Table 1
Cue Choice as Shown by Maze Retention Tests in Experiment I

Cue Choice	Training Group			
	One-Way*		Two-Way*	
	Training State			
	Non-drugged	Pento-barbital	Non-drugged	Pento-barbital
Response				
Md ^a	16	35	19	27
N ^b	5	10	11	14
% ^c	42	83	46	58
Place				
Md	17	42	16	45
N	6	2	10	5
%	50	17	42	21
Neither				
Md	15		20	37
N	1	0	3	5
%	8	0	12	21
Overall Median	17	37	20	36

*N = 24

^aMedian trials to criterion for cue

^bNumber of animals using cue

^cPercentage of animals in group using cue

mirror-image startbox, and their escape routes were recorded. If during training the "place" of the ladder had been associated with three right turns, during testing the route to the ladder consisted of a left turn followed by two rights. Thus, rats were forced to choose between going to the place of the ladder via a new route or following the sequence of responses they had learned during training. Rats that got lost during testing were rescued by hand, when necessary, as were rats that chose response routes during testing. The place or response choice of the first test trial was used to score each rat, unless this trial conflicted with the remaining two test trials. In the latter case, the second and third trials were then used as the score.

Results and Discussion

The results in Table 1 show that regardless of training group, drugged rats learned slower than nondrugged rats. A Mann-Whitney U test done with individual scores of the one-way animals between drugged and nondrugged groups, and a Wilcoxon matched-pairs signed ranks test, done with the individual paired drugged and nondrugged scores of two-way animals, yielded significant differences between drugged and nondrugged learning rates ($U = 14$, $p < .01$; $T = 1$, $p < .01$). The overall median trials to criterion for the one-way drugged and two-way drugged animals were 37 and 36, respectively; the overall median trials to criterion for one-way nondrugged and two-way nondrugged trials were 17 and 20, respectively. The fact that the medians are nearly the same for each training method in a particular state indicates that there was no transfer of learning between the states for the two-way animals. This, in turn, demonstrates state-dependent control of performance.

Table 1 also shows that most drugged trained rats learned response sequences, i.e., used response cues,

whereas many nondrugged trained rats learned a place in the maze, i.e., used place cues. In the one-way group, 10 of 12 drugged rats chose response cues, while only 2 of 12 chose place cues. This difference in cue use is significant ($p < .05$) according to the binomial test. Among nondrugged one-way animals, 5 of 11 chose response cues and 6 of 11 chose place cues (difference not significant according to the binomial test). In the two-way group, 14 of the 19 drugged rats used response cues in the drugged state, while only 5 of 19 used place cues ($p < .05$ according to the binomial test). Rats classified as using neither cue were not included in the binomial test computation. The cue selection made in each training state was a function of the training state itself, since the same cue selections were obtained in both the one-way and the two-way groups. Drugged rats primarily used response cues, while nondrugged rats selected place cues as often as response cues.

Although most of the cues selected during testing were clearly either a place in the maze or a response sequence, some rats failed to make a clear choice of either. These animals are grouped under the heading "neither" in Table 1. The reason for these rats' being confused when tested is not apparent. However, it might be related to the third important finding of this experiment: two-way trained rats used different cues in drugged and nondrugged states. Among the two-way rats that made a clear cue choice in each training state, only 4 of 19 used the same cue in both states, while 15 of 19 rats used a different cue ($p < .01$, binomial test). It seems that a rat that used a response cue in the nondrugged state had a conflict in also using a response cue in the drugged state. This conflict may explain why some rats in the drugged state could not make a clear choice of either cue. The use of the response cue is preferred in the drugged state, but there is some difficulty in using the same cue in both the drugged and the nondrugged states. Perhaps some drugged rats who had already learned the maze by learning a response sequence in the nondrugged state were unable to learn a place in the drugged state and were consequently forced to learn with a compromise of place and response cues while in the drugged state.

The results of this experiment indicate that drugged trained rats have greater difficulty learning to solve maze problems than do nondrugged trained rats, and that some of this difficulty might result from the drugged rats' failure to learn place cues in a drugged state. Nondrugged rats, on the other hand, appeared able to use place and response cues equally well. Also, the results showed that two-way trained rats used different cues in drugged and nondrugged learning states.

EXPERIMENT 2

In the first experiment, the rats were allowed a free choice of cues in learning an escape route, even though

the escape route itself was determined by the experimenter. From the results, we inferred that drugged rats are limited to the use of response cues, in contrast to the nondrugged rats, which use either place or response cues. In the second experiment, drugged and nondrugged rats were allowed to choose escape routes as well as escape cues. The question we were interested in was whether the escape routes chosen by drugged and nondrugged trained rats would be the same, given the opportunity to choose among a number of equivalent alternative routes, and whether the drugged and nondrugged route choices would correspond to the differences in cue choices found in the first experiment.

Subjects and Procedure

Twenty-four male Wistar rats were used. The rats were randomly assigned to either one-way or two-way training groups of 12 rats each. One-way rats were divided equally between drugged and nondrugged training groups.

All inserts were removed from the maze to produce a Dashiell pattern maze. The start and goal areas were the four corner alleys of the maze. When one area was used as the start area, the diagonally opposite corner was used as the goal area. Each startbox and diagonally opposite goal area was used an equal number of times for drugged and nondrugged training with both training groups. Rats in both groups were trained from the start in one corner of the maze to swim until they found the ladder located in the diagonally opposite corner. Rats were trained in daily sessions of 5 trials. There was no training criterion, so training was terminated after 25 trials, a number of trials sufficient for rats to develop a stable route of preference through the maze. Two-way rats were given a total of 50 trials each, 25 in each training state. Performances were scored on each trial by counting the alley intersections used en route to the ladder. An arbitrary score ceiling of eight intersections per trial was used. The actual route taken by a rat on each of its trials was also recorded.

Results and Discussion

Figure 2 shows the typical escape routes chosen by one-way and two-way drugged and nondrugged rats. The route that was eventually chosen by a rat depended

Figure 2. The Dashiell pattern used in Experiment 2. The solid, arrowed line shows a typical stabilized route for a drugged rat. The broken, arrowed line shows a typical stabilized route used by a nondrugged rat. The diagonally opposite corner was the goal area for each start area.

Figure 3. The graph shows the mean number of intersections used by drugged and nondrugged rats over 25 trials in the Dashiell maze pattern. Drugged rats stabilized to a two-intersection route, while nondrugged rats stabilized to a four-intersection route.

entirely upon whether it was drugged or nondrugged, and not upon whether it was a one-way or two-way trained animal. Nondrugged rats stabilized to a diagonal zigzag route through the maze using four intersections, equivalent to the dashed line in Figure 2. The drugged rats stabilized to routes around the perimeter of the maze and used two intersections, equivalent to the solid line in Figure 2. In Figure 3, the mean number of intersections for all drugged and nondrugged trained rats are plotted in blocks of five swim trials. It shows that: the routes of both drugged and nondrugged rats stabilized in about 20 trials; nondrugged rats chose the route most directly oriented toward the ladder; drugged rats chose a route with the lesser number of turns.

These results, like those of the first experiment, suggest that drugged rats learned to use response cues, while nondrugged rats can use either place or response cues, but eventually use place cues. The free choice of routes in this experiment showed that drugged rats stabilized to a route around the perimeter of the maze, a route based on a two-turn response sequence. The nondrugged rats, on the other hand, seemed to orient directly to the place or location of the ladder, and swam diagonally through the maze. These route choices seem to correspond to the place and response cue choices made by drugged and nondrugged rats in Experiment 1, where the routes were fixed by the experimenter. Thus, the earlier findings that drugged and nondrugged rats use different cues to learn seem to be corroborated.

EXPERIMENT 3

In the two previous experiments, the choice of cues used to escape from the water maze was made by the

rats. In this experiment, we wished to find out whether the experimenters' description of the cues (place and response) the animals used to solve the maze in the first two experiments does, in fact, operationally correspond to a location in the maze (place) or to a sequence of turns (response). To do this, we forced the rats to learn to escape from the maze, using either a location or a series of turns, and compared their learning with that of the rats in the first experiment, which chose their cues. If the learning rates are comparable, we will conclude that the experimenters' definition of place and response fit operationally with the rats' definition of place and response. Furthermore, if the drugged state limits the use of cues and the drugged rats have difficulty in using place cues, as suggested in the first experiment, then the learning rates of drugged rats required to use place cues would be significantly less than those of drugged rats required to learn response cues. There should be no limitation on cue use if the drugged and the nondrugged states are on a single generalization gradient and the discriminative stimulus is the animal's state. Finally, this experiment also permitted another look at the overall learning rates of drugged and nondrugged rats.

Subjects and Procedure

Fourteen Wistar and 10 Long-Evans male rats were used. The 24 rats were assigned randomly to one of two groups of 12 rats each, receiving either one-way drugged or one-way nondrugged training. Only one-way training was used in this experiment. The rats were assigned to use either a place or a response cue to escape from the water maze. The maze was arranged as shown in Figure 1, except that both startboxes (S_1 and S_2) were used for all rats. Rats required to learn a place in the water maze were trained to swim to the same location on each trial, while their starting position was alternated between the two startboxes, according to the Gellerman series (Gellerman, 1933). Rats required to learn a response sequence were required to make the same series of three consecutive left

Figure 4. The maze arrangement used in Experiments 3 and 4. Startboxes are designated S_1 and S_2 . Goal areas are designated G_2 , G_3 , G_6 , and G_7 . The solid, arrowed line shows a typical route used to learn a place cue. The dashed, arrowed line shows a typical route used to learn a response cue. Routes are shown alternated between the two startboxes.

Table 2
Median Trials to Criterion for Rats Required to Use Place or Response Cues

Cues	State	
	Nondrugged	Pentobarbital
Response	16	27
Place	14	50
Overall Median Trials to Criterion	15	39

or right turns on each trial, while their starting positions were alternated between two different startboxes and the ladder was moved to a location that permitted learning of a response sequence. Typical "response" and "place" training routes are shown in Figure 4. The four goal areas, indicated in Figure 4 as G_2 , G_3 , G_6 , and G_7 , and the left and right response sequences were assigned to an equal number of animals within the drugged and nondrugged training groups. Because considerable learning difficulty was predicted for drugged rats forced to learn a place, a ceiling of 50 training trials was used with all animals. Individual performances were scored by number of trials needed to reach a training criterion of 8 out of 10 errorless trials.

Results and Discussion

The results, summarized in Table 2, show that drugged "place" rats learned at a slower rate than drugged "response" rats. The median trials to criterion were 50 for drugged "place" rats and 27 for drugged "response" rats. The learning rates for these two groups are significantly different (Mann-Whitney U test computed with individual scores, two-tailed, $U = 2$, $p < .01$). The nondrugged animals were not different in their ability to learn using place and response cues; the nondrugged place and response medians were 14 and 16, respectively. The results of this experiment confirm the earlier observation that drugged rats are slower learners than nondrugged rats in these particular maze tasks. The overall median trials to criterion for drugged rats was 39 as compared to 15 for nondrugged rats (Mann-Whitney U test, two-tailed, $U = 15$, $p < .01$).

Table 3 gives the median trials to criterion for the rats in the present experiment and compares them to the rats in Experiment 1. None of the compared learning rates are significantly different according to the Mann-Whitney U test, two-tailed, computed with individual scores. The one-way rats in this experiment that were forced to use either place or response cues learned at about the same rate as the one-way rats in Experiment 1, which chose the same respective cues. This suggests that place and response, as defined in these experiments, operationally refer to a maze location or turning point.

The present experiment also confirms the earlier observations that drugged rats learn response sequences in solving problems and have a great deal of difficulty in learning place cues. This suggests that drugged rats might be limited to the learning cues provided by feedback from their own body movements, while nondrugged rats seem able to use both environmental and movement feedback information.

EXPERIMENT 4

One of the findings in Experiment 1 was that rats trained in the same type of maze escape route in both the drugged and nondrugged states used different cues in each of the training states. The fourth experiment was done to extend this observation. Two-way animals required to use the same cue in both drugged and nondrugged states were expected to have greater difficulty in the discrimination training procedure than animals allowed to use different cues. This experiment also extended the comparison of learning rates for place and response cues, further testing the operational definition of place and response.

Subjects and Procedure

Twenty-four male Wistar rats were randomly assigned to one of two equal-sized groups: 12 "same-cue" animals were forced to use the same cue in drugged and nondrugged training; 12 "different-cue" animals were forced to use different cues in drugged and nondrugged training. The training procedure for this experiment was essentially the same as that used in Experiment 3, except all rats were trained in the two-way procedure. The maze was arranged as it was in Experiment 3. The combinations of goal areas and place and response turn sequences shown in Figure 4 were assigned equally often within the same-cue and different-cue groups. Figure 4 also shows typical routes for the forced training of places and responses.

If a rat in the same-cue group was assigned a place cue in the nondrugged state, it was also assigned a place cue in the drugged state. Different-cue-group rats were assigned place cues in one state and response cues in the other state. All other aspects of two-way training were the same as described earlier, including the counterbalanced order of the state of the first training session. Also, equal numbers of place and response cues were assigned to drugged and nondrugged conditions.

The number of trials to an 8/10 correct criterion was used to score learning rates. A 50-training-trial maximum was used again as a ceiling. The relative difficulty of learning with the same or different cues was assessed by comparing the total number of trials necessary for a rat to learn to criterion in both states.

Results and Discussion

The results of this experiment revealed that rats learning comparable maze tasks in both a drugged and nondrugged state took longer to reach training criterion if required to use the same cue (whether place or response) in both states (Mann-Whitney U test, one-tailed, computed on individual scores, $U = 37$, $p < .025$). This result supports the conclusions of Experiment 1 that rats have difficulty using the same cue in both the drugged and nondrugged states and further supports the conclusion that rats, given a choice to use either place or response cues, may choose different cues in each of the states to keep the states behaviorally separated. The median trials to criterion for two-way animals from this experiment are presented in Table 3, where they are also compared to their counterparts from Experiment 1 which learned the maze using the same cue and state combination. The median trials to criterion for these animals are not different, according to the

Table 3
Median Trials to Criterion for Comparable Task Groups
from Experiments 1, 3, and 4

Training	Group	Experiment		
		1	3	4
One-way	NP	17 (6)	14 (6)	
	NR	16 (5)	16 (6)	
	DP	42 (2)	50 (6)	
	DR	35 (10)	27 (6)	
Two-way	NP	16 (11)		20 (12)
	NR	19 (10)		28 (12)
	DP	45 (6)		50 (12)
	DR	27 (13)		26 (12)

Group abbreviations—NP = no drug, place; NR = no drug, response; DP = drug, place; DR = drug, response; Drug = pentobarbital. Ns are given parenthetically.

Mann-Whitney U test, two-tailed, computed on their individual scores. Again, the two-way comparisons support the conclusion that place and responses, as operationally defined in these experiments, are operationally the same thing for both rat and experimenter.

DISCUSSION

The preceding experiments were conducted to determine whether a drugged state serves as a discriminative stimulus in state-dependent learning, and whether drugged and nondrugged states are discrete learning states at dissociative drug dosages. The results showed that (1) drugged rats learned at a slower rate than nondrugged rats; (2) drugged and nondrugged rats used different cues to learn to escape from the water maze: drugged rats learned only response sequences to escape from the maze, while nondrugged rats learned either place of exit or a response sequence; (3) individual rats usually selected and used different cues in drugged and nondrugged states; (4) learning was impaired when animals were required to use the same cue in both drugged and nondrugged states. We believe these findings apply to instances where rats are required to use place or response cues, as well as when permitted to choose them.

We believe that the above findings can be generalized to either a 2 by 2 repeated-measures design (normally trained-drugged tested, N-D; or drugged trained-normally tested, D-N) or a discrimination design. The results obtained from the one-way trained rats (modified 2 by 2 design) were the same as those obtained from the two-way trained rats (discrimination design). These findings also held, whether the rats were given a choice of cue use or were required to use place or response cues in learning to escape from the maze. It is clear that drugged and nondrugged rats learned different things. Furthermore, the differential selection of cues for learning, i.e., place or response, can be interpreted as the animals' basis for the maintenance of discrete learning

states. It is precisely for this reason that we believe that the drug-stimulus hypothesis is not the basis for state-dependent learning. Rather, the animal uses different cues for the different states and does not control his behavior by using the drugged state vs. normal state as on a stimulus continuum. The drugged state and the normal state do not appear to be on the same continuum since drugged rats are restricted in their cue use. Drugged learning is not the same as normal learning. Drugged learning states are dissociated because drugs impair the capacity of an animal to use environmental cues, and he then makes use of different contingencies and strategies, i.e., response sequences.

The conclusion that pentobarbital might restrict the use of environmental cues commonly used in learning might explain the drug-imposed restriction of exploratory and curiosity behaviors observed by others (Barry, Wagner, & Miller, 1962; Bloch & Silva, 1959; Sachs, 1967). It must be pointed out, however, that the pentobarbital restriction of environmental cues noted in these and other experiments was not a restriction on the input of any particular sensory modality. Pentobarbital drugged rats are not rendered blind, deaf, or somesthetically anesthetized, although these capacities are probably impaired by the intoxication. It is suggested here that pentobarbital limits and greatly impairs the processing of sensory information, even though it does not abolish it. Another important observation is that the drugged animals in the present experiments did not suffer from permanent motor impairment. Instead, they learned to swim proficiently through the maze as training progressed. Drug behavior tolerance studies have also made note of the ability of an animal to become skilled at a particular task while drugged, yet fail in other similar tasks in which it had no drug training (Kalant, LeBlanc, & Gibbons, 1971; Schuster & Zimmerman, 1961).

Because the pentobarbital drugged animals had adequate sensory inputs and retained the capacity to respond, it is hypothesized that they suffered a restriction in their ability to integrate sensory information with motor responses. When a nondrugged trained animal is drugged, the resulting failure of sensorimotor integration produces a loss in the response guided by that integration. Responses learned in a drugged state are largely dependent on kinesthetic cues. When a drug wears off, the kinesthetic cues become lost in a flood of novel environmental cues and the response dependent on these kinesthetic cues is lost with them. Thus, state-dependent learning might be a consequence of a drug limitation that changes learning-demand characteristics, as drugged animals have to deal with the world without normal sensorimotor integration.

Our hypothesis is similar to the simple-complex hypothesis, advanced by Sachs (1967) and our data are certainly consistent with it. Basically, the simple-complex hypothesis is that drugged animals do not attend to all of the features of their environment,

because they have impaired cognitive functioning and, consequently, they learn simpler problems. However, when they are no longer drugged, they do attend to their environment, and explore it. The exploratory response competes and interferes with other responses and dissociation appears. Our data clearly suggest that drugged animals have impaired cognitive functioning. It might even be argued that response learning is a more primitive form of learning than place learning. But, because our drugged rats did not appear to be blind, deaf, or somesthetically anesthetized, and because we could not get them to learn using place cues, we believe that a process had been disrupted; the process of sensorimotor integration. Our hypothesis, like the response-initiation hypothesis, supposes that the process that integrates the response is interfered with. We differ from that hypothesis because we believe the drugged state limits the kinds of sensory information that can be integrated, or processed, for a particular state, and has not limited the integration to a response-initiation loss.

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