STIMULUS-RESPONSE SPATIAL CONTIGUITY VS. S-R SPATIAL DISCONTIGUITY IN AUDITORY SPATIAL TASKS
I. ACQUISITION BY NORMAL DOGS

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Abstract. Twelve dogs were trained in spatial tasks with auditory location cues. One group, tested on delayed response with stimuli and responses spatially contiguous, solved the task at once, whereas the other group, trained with actual stimuli and responses spatially discontiguous, attained criterion after errors. The differences in behavior of these groups suggest that two learning strategies may be involved. In the first group — approaching a specific (directly determined by auditory targeting reflex) feeder by an unspecific directional response. In the other group — approaching a non-specific feeder by a specific directional response, established in the differentiation learning.

INTRODUCTION

In the analysis of physiological mechanism of delayed reactions with different methods of choice (11), particular attention has been paid to those spatial tests in which directional responses were determined by different location cues. Two kinds of auditory location cues have been described there, differing in their determining properties: one, which evokes in animals an orienting reaction allied with response towards foodplace, and another, eliciting an orienting reaction not allied with directional response towards food. Depending on spatial relations between the stimulus and response, a striking difference in attaining criterion of learning may be observed for each of these conditions (8, 9, 11, 13). The present paper deals with these differences comparing
animals performance trained in two tasks with spatial choice based on auditory location cues. In the first learning situation — stimuli and responses are spatially contiguous, whereas in the second — spatially discontiguous with directional responses. It should be added that these two tasks were primarily selected to study the effects of medial prefrontal lesion on animals retention. However, because of striking differences observed in animals behavior during preoperative learning, we have decided to discuss preoperative performance of animals separately in this paper.

METHOD

Subjects. Twelve experimentally naive mongrel dogs were used. They lived in individual boxes in the animal house and were fed once daily 15 to 20 h before testing.

Experimental situation

Six dogs were trained in the delayed response test and six in the go-left, go-right task. All animals were trained in a rectangular room 4 \times 8 m with three widely separated food dispensers arranged on the floor as shown in Fig. 1. Each food dispenser consisted of a box containing 10 foodcups mounted on a rotating disc. An opening on the top of the box provided access to one cup only. The cups were baited with food and could be brought into position, one at a time, by a partial rotation of the disc. Rotation of the disc was activated remotely by the experimenter, who was seated at a switchboard behind the starting platform. Food rewards in both tasks consisted of bread soaked in broth with small addition of boiled meat (approximately 5 g). The photocell equipment was mounted in front of each foodbox. A wooden screen, 83 cm high, was interposed between the starting platform and the experimenter.

On the delayed response test three food dispensers were used. On the top of each foodbox was a buzzer which could be remotely activated by experimenter — the intensity of the signal at the starting place was
approximately 46 dB. The delayed response involved leashing the animals during the delay period. The animals could be leashed at the starting position by a 82 cm long leash attached manually to a hook fixed at the screen. Attaching the leash activated an electronic timer. Releasing the animal activated another timer, which stopped whenever the animal approached a foodwell.

On the go-left, go-right task the middle foodbox was screened and only two side feeders, left and right, were used. On this test the animals were responding to the actual auditory stimuli. The stimuli were produced by a square-wave generator set to deliver 50-ms pulses at frequency 10/s through either one of two speakers. The speakers were located at the starting place in the vertical plane: one 17 cm and another 110 cm above the floor. The intensity of the signal at the starting place was approximately 46 dB, which was slightly above the background noise. Stimulus onset activated an electronic timer which stopped whenever the animal approached a foodwell.

**Testing procedure**

*Delayed reaction.* On the first day of preliminary training, a dog was familiarized with the experimental room for 10 min and received a small amount of food on the starting platform. From the next day on the dog received food from three feeders, five portions from each, delivered in random order. At the same time, the dog was trained to approach a given feeder in response to the sound of a moving bowl with a new portion of food. Having received the food, the dog learned to return to the starting place, since going back to the platform constituted the necessary condition for being given the next portion of food. The next stage of training was begun if, in the course of one session, the dog approached the feeders to the sound emitted by a moving bowl in fifteen errorless trials. At this stage, buzzers were introduced; a buzzer placed on a feeder and turned on for 3 s indicated the correct feeder in a given trial. If the dog approached the right feeder, the response was reinforced with food. When the dog chose a feeder which was not signalled, the food was not given, the response was counted as an error and the trial was repeated after the usual intertrial interval. If a dog approached an incorrect feeder and, on not finding any food there, self-corrected itself, i.e., moved next to the feeder indicated in that trial, food was not given. A direct movement towards the correct feeder was thus the necessary condition for obtaining reinforcement.

After an errorless session was carried out in the above-described manner, a 0-s delay was introduced. It was done by restraining a dog
on a leash in the starting place for 15 s before the presentation of the stimulus. Following the 15-s restraint period, the buzzer was turned on for 3 s and the dog was released simultaneously with the stimulus offset. The acquisition was begun after attaining the preliminary criterion consisting of 15 errorless trials in one experimental session conducted in the just described way.

Acquisition consisted of 4 successive series — each series consisted of 60 trials. During the first series, trials with 15-s delay were presented. During the second, third and fourth series delays of 60-s were used with the third series differing from the rest in that a distracting stimulus was used every trial. This distraction consisted in giving a dog an extra portion of food in the starting place during the period of delay. It was a small portion of minced meat given in 15-s of delay, which the dog could ingest in approximately 15 s.

A daily experimental session consisted of 15 trials during which all feeders were signalled in random order. The intertrial interval was 2 min. Whenever the animal made an error, the procedure was the same as during the initial training, i.e., the dog was not given food and the trial was repeated with 0-s delay. In each series the dogs were trained to a criterion of 90% correct responses in 4 successive daily experimental sessions, i.e., in 60 trials.

Go-left, go-right task. As in the delayed response task, on the first day of preliminary training the dogs were familiarized with the experimental room and were then trained to approach the feeders in response to the sound of a moving bowl. An experimental session consisted of 18 trials with every feeder being signalled 9 times in random order. The procedure in this task, however, unlike the one used in the delayed response task, did not require the dog to be leashed on the starting platform and the animal remained unrestrained for the whole duration of the sessions. But, as in the previous task, the dogs were encouraged to return to the starting place soon after receiving food. After a session during which a dog went 18 times from the platform to the correct feeder in response to the sound of the bowl, the acquisition was begun.

Acquisition began with the introduction of conditioned stimuli in the starting place. A rhythmic auditory stimulus was presented from either of two speakers positioned higher and lower above the floor, signalling respectively a response towards the left and the right feeder. Similarly as during the pretraining, each of the two feeders was signalled in 9 trials in random order. The intervals between the successive stimulus presentations were 50–70 s. These intervals were sometimes prolonged
due to the intertrial responses. If it happened that an animal approached a feeder during the last 10 s of the intertrial interval, this interval was prolonged by 10 s, so that each stimulus onset was preceded by a period of non-responding.

In order to establish the correct choice reaction to the presented stimuli, a bowl was moved in the signalled feeder, a few seconds (4–11) after the stimulus onset. The animals, having been previously pretrained, reacted to the sound made by the bowl by turning the head in its direction and approaching a given feeder. The stimulus was turned off when the animal reached the feeder and began eating. With this procedure being used, the dog soon began to approach one of the feeders in response to the auditory stimulus alone, i.e., without waiting for the sound of the bowl.

If the animal approached the correct feeder, a bowl containing food moved into position inside it. If, on the other hand, the dog approached an incorrect feeder, the stimulus was terminated, the trial was scored as an error, and the stimulus was repeated after the usual interval until the animal corrected its response. If, however, the animal made 4 errors in succession — the first initial error and 3 repetitive errors — within a given trial, the same stimulus was repeated for the fifth time and the food delivered in the correct feeder immediately after the stimulus onset. Thus, in those conditions, every trial ended with the delivery of food, even if the conditioned stimulus was repeated several times as the result of the animal making repetitive errors. If a dog happened not to approach a feeder during the 20-s stimulus presentation, food was given in the correct feeder and the stimulus was turned off. Such a trial, without an active choice, was not included in the total trials-to-criterion score.

The trials-to-criterion score included the first presentation of the stimulus in a given trial, providing that the animal responded to it with an active choice. Further presentation of the stimulus in a given trial which did not end with the food being delivered because of a wrong choice, were included in the score of repetitive errors. The dogs were trained to the criterion of 90% correct responses in 90 trials which consisted of 5 successive experimental sessions.

RESULTS

Delayed response task. The first stage of preliminary training before the buzzer was introduced, required in individual animals 2–4 days. In the next stage during which the animals were responding to the actual buzzer, the criterion of an errorless session was reached at once, whereas analogous criterion with 0-s delay trials was attained after 0–2 errors.
During acquisition all the dogs in the series with 15-s delay reached criterion. Also, in both series with 60-s delay without distraction, all the dogs of this group reached the criterion at once. Only in the series with a 60-s delay with distraction did two dogs, M8 and M10, require additional trials to attain the criterion. M8 reached the criterion level after one additional sessions, having made 4 errors, and M10 after 5 sessions during which 12 errors were committed (Table I). During the whole training all the animals committed 55 errors, including the errors committed during the criterion stage.

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<thead>
<tr>
<th>Dog</th>
<th>Errors to criterion</th>
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<tr>
<td></td>
<td>Delay in seconds</td>
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<tr>
<td></td>
<td>15</td>
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<tr>
<td>M6</td>
<td>0</td>
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<td>M7</td>
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<td>M8</td>
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It should be mentioned that the dogs, after making an error, attempted to correct themselves (12), although, as indicated earlier, these runs were never reinforced by food. Since the conditions of the experiment involved a triple choice, it was possible for a dog which had chosen an incorrect feeder to choose another one from the remaining two. This fact made it possible to ascertain that the attempted corrections did not result from a dog's random search for food. Thus, the committed errors were followed by 45 "correct" self-corrections and 1 erroneous. In nine cases no tendency for self-corrections was observed.

During the training, a certain number of intertrial responses was observed in dogs examining the feeders during the intertrial intervals. The dogs made 8-65 intertrial responses during the first session with 15-s delay, but the numbers decreased to reach, at the end of training, the level of 2-7. It should be added that no relation was observed between the number of intertrial responses and the number of errors. An illustration of this can be provided by sessions with 15-s delay during which all the dogs reached the criterion within the first 60 trials, although the number of intertrial responses made by individual dogs varied over a wide range of values.
Regarding other forms of general behavior, the dogs behaved naturally between the trials, walking at first around the room for several seconds and then returning to the starting place where they stood, sat or lay before the presentation of a stimulus. They did not assume a constant bodily posture in the starting place, either immediately before or during the presentation of a stimulus. Irrespective of a body posture adopted by an animal, the application of the buzzer induced a head movement towards the source of the stimulus. Maintaining a steady posture during the delay was not a necessary condition for responding correctly: it is evidenced by the trials with distraction which provoked the dog to change its position on the platform.

With two dogs, M10 and M11, the choice reaction time was automatically recorded; it was the time taken by a dog to approach a chosen feeder after it had been released. The reaction time varied between 1.4–3 s and will be presented on a curve in the second part of this study (in preparation).

Go-left, go-right task. All the dogs behaved similarly during the first stage of training: they mastered the task of approaching the correct feeder in response to the sound made by the bowl on the first (3 dogs) or on the second (3 dogs) day of preliminary training.

After the introduction of stimuli presented from loudspeakers positioned on the starting platform, it was observed, that the first active responses — dogs approaching feeders without waiting for a click of the bowl — appeared already on the first day. Active responses on all the trials began to occur beginning with the 2nd–4th acquisition day. On the average, all the dogs reached the criterion after 143 trials (range 54–263), committing, on the average, 86 errors (range 25–165). The number of trials and errors for individual dogs prior to attaining criterion is shown in Table II. It may be added that in three dogs, a great majority of errors are made up of responses to the left feeder (M1,

<table>
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<tr>
<th>Dog</th>
<th>Trials to criterion</th>
<th>Errors to criterion</th>
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<tr>
<td></td>
<td></td>
<td>Initial</td>
</tr>
<tr>
<td>S–R</td>
<td>M1</td>
<td>145</td>
</tr>
<tr>
<td></td>
<td>M2</td>
<td>156</td>
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<tr>
<td>spatially discontiguous</td>
<td>M3</td>
<td>263</td>
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<td></td>
<td>M4</td>
<td>96</td>
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<td></td>
<td>M5</td>
<td>54</td>
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<td></td>
<td>C1</td>
<td>147</td>
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M2, C1), and in two dogs — of responses to the right one (M3, M4). One dog's errors were completely balanced (M5).

As on the delayed response test, the dogs were observed to make a number of intertrial responses during the first phase of training on this task. These responses were extinguished in the course of training and at criterion level the average number of responses for one dog in one session dropped to 6-0.

All the dogs spent most of the time during the intertrial intervals in the starting place; standing or sitting, they remained in the middle of the platform facing the speakers. During the early trials the dogs faced the stimulus source fixating the speaker from which the stimulus was presented, but those reactions gradually disappeared and were apparent only for a fraction of a second during later trials. Successively, the presentation of the stimulus was accompanied by a slight quick head movement to the left or right. Next, the dogs turned and moved in the direction of either the left or the right feeder, depending on the direction of the initial head movement. A dog which did not maintain a constant position on the platform at the stimulus presentation was likely to make a random choice. If its position was such that there was a feeder in its field of vision, the dog usually responded to the stimulus by approaching that feeder. Thus in contrast to the animals trained on the delayed response task, the correctness of responses made by animals in this group was observed to be dependent on the way an animal positioned itself on the starting platform.

Responses latencies were recorded by experimenter with a stopwatch from the stimulus onset till the moment a dog left the platform. During the period close to the attainment of criterion the dogs usually left the platform within the first second of the stimulus presentation, and, as a rule, reached the chosen feeder in the next 1-2 s. These data will be presented in the second part of this study.

DISCUSSION

The comparison of the speed of learning of the two groups reveals significant differences: while the dogs trained on delayed response task reached the criterion within first sessions, the dogs trained to respond to the actual stimuli committed a considerable number of errors prior to attaining the criterion. The difference in the number of trials and errors, as well as the difference in the dogs’ behavior in the starting place suggest that different mechanisms may be involved in the solution of both tasks.

It has been previously suggested (13) that tasks with directional
instrumental responses can probably be solved by two different methods. The author compared two groups of dogs trained on double choice tasks. The groups differed with respect to the location of stimuli which were spatially contiguous with responses for one group, and spatially discontiguous for the other. There was a difference, similar to the reported here, in the speed with which the two groups reached the criterion: such differences were also observed after the introduction of the 15-s delay in both groups. It was then suggested that when the stimuli and responses were spatially contiguous, the solution of the task was based on the localization of the correct feeder, independently of the animals' position. When, however, the stimuli were spatially discontiguous, the choice of the correct feeder was a function of the established head movement differentiation (left-right) related to the body axis of the subject.

Present results support this possibility. In the delayed response task where stimulus and response were spatially contiguous, the correct response was not observed to be dependent upon the bodily orientation adopted by an animal at the moment of release at the starting place. Additional changes in bodily orientation, induced by food delivered during delays at the starting platform, did not affect the solution of the task. Also the tendency for self-correction, observed when errors were made, provided additional evidence that the choice reaction in this task was not determined by a fixed kinesthetic pattern. During self-corrections the animals were able to approach the correct goal, although at that moment they were not at the starting place, but in front of an incorrect feeder.

Another type of behavior was observed on the go-left, go-right task in which the stimuli and responses were spatially discontiguous. Here, maintaining a fixed starting position at the stimulus presentation was an important factor for correct responding. With an animal assuming different bodily orientation, the same head turning could, obviously, initiate approach to different foodwells. Thus, the comparison of animals' behavior in these two spatial tests, both of them involving auditory location cues indicates, that the dogs trained with stimuli and responses spatially contiguous, solve the task by approaching a specific feeder by an unspecific directional response. On the contrary, the animals trained with stimuli and responses spatially discontiguous solve it by approaching a non-specific feeder on the basis of a specific directional response.

The mechanism responsible for the solution of spatial tasks was
closely investigated by Tolman and his group (16–18). Since a simple T-maze may be mastered either by “place” or “response” learning, the experimental procedure in a series of studies was modified in such a way, as to make the solution possible on the basis of one kind of learning only. Usually, for a place learning group the task requirements were such that the animals always had to choose the same arm of the maze, irrespective of the position of the starting place and turns (left or right) they had to make. The animals trained in response learning, on the other hand, were always required to make the same turn, irrespective of the starting place. It was expected that the differences in the speed of learning of those groups would reveal which of the two tendencies predominates in the behavior of normal rats. The results did not, however, turn out to be unequivocal (1, 2, 8, 15); it is now generally accepted that only in conditions when extra-maze cues of both arms of the maze are sufficiently different, place learning will be observed to prevail over response learning.\(^1\) (15, 19, 20).

The conclusion that learning in a spatial situation depends on stimulus conditions, is also drawn by authors studying the behavior of 9-mo old infants in the double choice task (4, 7). As has been demonstrated by Piaget (14) beginning with this age the children watching an object hidden in one place, are able to search for it successfully. However, if the object is successively hidden in another place, the child persists in searching for it in the first place. Variations in experimental procedure (4–6) were intended to determine whether the source of errors is due to the inability to overcome place, or response learning. The results seem to indicate, that at this age learning of a directional response prevails (3) and only under certain conditions, with very distinct visual cues, the data may suggest relaying on allocentric strategy in task solving (4).

The present data may also be interpreted as supporting the possibility of place, or, response learning, involved in spatial choice. They also indicate, that beyond visual cues, there may be still another factor

\(^1\) It should be added, however, that the conditions of the present experiment created a more difficult differentiation task than was the case in Tolman’s studies. There, only one arm of the maze, or one turn leading to food was the correct one. In our case, one of three feeders was correct depending on the stimulus presented in a given trial. Likewise, in the task which required a choice of a single correct turn — in our situation two turns were correct, each established to a different stimulus and reinforced by food.
determining animals strategy in solving a spatial task. The factor responsible for the predominance of one, or another way of learning in the present conditions appeared to be location of stimuli, i.e., whether their sources were spatially contiguous, or discontiguous, with responses.

A question can be posed as to why the location of the auditory stimulus, contiguous or discontiguous with the responses, plays such an important role in determining the reaction of choice. In the theoretical considerations concerned with this issue (11) it has been emphasized that the orienting reaction can play a different role depending on the location of the source of stimuli in both these experimental conditions. In the case of delayed response it is directed towards the source of stimulus and is thus congruent with the instrumental alimentary reflex consisting in the run to the respective feeder. When, on the other hand, the stimuli are placed on the starting platform, the orienting reaction directed towards the source of stimuli is incongruent with the alimentary directional response and cannot thus determine in a “natural” way the correct form of instrumental responding. Consequently, the correct response appeared in the latter case only after a period of training which established inhibition of incorrect movement (11).

Discussing the problem of orienting reflex as an example of consummatory unconditioned reflex to biologically neutral stimuli, Konorski, in his last monograph (10) introduced a term “targeting reflex” thus separating one component of orienting reflex, apart from a number of its autonomic and unspecific elements. The role of the targeting reflex would, according to him, consist in the best adjustment of analyzers to the perception of the stimulus, so that its effects consist of directing the head, eyes and ears towards the stimulus source. We can thus conclude, that in spatial test with auditory location cues spatially contiguous with responses, the animals choice is directly determined by auditory targeting reflex and therefore involves no training. The targeting reflex in this case does not habituate, since, in the course of training being reinforced by food, is transformed into an alimentary response. If, on the other hand, the stimuli are presented from the platform, then the auditory cues evoke a targeting reflex spatially discontiguous with the direction of a locomotor response. Therefore, in this case, the correct response is established in the effect of an additional association formed between the kinesthesis of the targeting reflex and the kinesthesis of a particular head movement accomplished in the differentiation process.

The possibility, that stimulus-response spatial contiguity, or discontiguity, may be an important factor determining the mechanism
of solving spatial tasks, is further supported by their selective impairment obtained in dogs after medial prefrontal lesions.

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REFERENCES


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