

Overshadowing in Landmark Learning: Touch-Screen Studies With Pigeons and Humans

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Overshadowing in landmark learning was studied in pigeons and undergraduates using a touch-screen spatial search task. Ss searched for an unmarked goal presented in varied locations on a computer screen. Graphic stimuli served as landmarks. The effect of the presence of other landmarks on the control acquired by a given landmark was assessed using a design in which each S was trained with 2 sets of landmarks. Both pigeons (Experiment 1) and humans (Experiments 2–4) showed evidence of learning more about a landmark that was the closest landmark of its set to the goal than about a landmark that was of equal distance to the goal but was not the closest landmark of its set. That is, control by a landmark was overshadowed when it occurred together with a landmark that was closer to the goal. Landmark effectiveness appears to depend not only on the absolute properties of a landmark but on relative factors. The relevance of basic principles of associative learning to spatial landmark learning is discussed.

Many organisms use visual landmarks to locate, remember, and return to important locations (see Gallistel, 1990). The location of a goal can be encoded in terms of its distance and direction from visual landmarks. Experiments in which visual stimuli were manipulated during a search test provide convincing evidence for control of searching by visual landmarks in a variety of animals, including rodents (e.g., Collett, Cartwright, & Smith, 1986; Etienne, Teroni, Hurni, & Portenier, 1990; Suzuki, Augerinos, & Black, 1980), birds (e.g., Cheng, 1988, 1989, 1990; Cheng & Sherry, 1992; Spetch & Edwards, 1988; Vander Wall, 1982), cephalopods (Mather, 1991), and insects (e.g., Cartwright & Collett, 1982, 1983; Couvillon, Leiato, & Bitterman, 1991; Dyer & Gould, 1983; Tinbergen, 1972; Wehner & Räber, 1979). In a series of studies in which a laboratory open-field task was used to investigate pigeons' use of local visual landmarks when searching for hidden food, Cheng and his colleagues made considerable progress toward understanding the mechanisms in which pigeons derive distance and direction information from visual landmarks (Cheng, 1988, 1989, 1990, 1994; Cheng & Sherry, 1992).

Recently, Spetch, Cheng, and Mondloch (1992) intro-

duced a touch-screen analog task for investigating pigeons' use of visual landmarks for spatial search. This task was modeled after Cheng's (1988) laboratory open-field task in which pigeons searched for a hidden goal in a circumscribed spatial arena, and stimuli near the goal were provided as landmarks. In the touch-screen version of this task, the vertical surface of a monitor screen serves as a two-dimensional spatial arena, and an attached touch-frame records the location of search pecks. Visual stimuli displayed on the computer screen serve as landmarks for locating an unmarked goal area on the screen. Spetch et al. found that pigeons' use of graphic landmarks in this touch-screen task was similar in several ways to their reported use of object landmarks in a three-dimensional spatial arena. A subsequent study by Spetch and Wilkie (1994) revealed additional similarities between landmark control in the touch-screen task and landmark control reported in open-field settings. The touch-screen task offers the practical advantages inherent in the use of automated operant technology for stimulus presentations and data recording, and it is particularly useful for studies that require a large number of test trials.

Three subsequent investigations using the touch-screen task (Spetch & Mondloch, 1993; Spetch & Wilkie, 1994; Cheng & Spetch, in press) have focused on the landmark control that develops in training when multiple visual stimuli are presented near the goal. In each of these studies, the goal was in a fixed location relative to an array of two or more stimuli displayed on the screen, but the absolute screen location of the goal and the corresponding stimulus array varied across trials. The landmark array and corresponding goal was moved without rotation so that the orientation of the screen provided a directionally stable frame of reference. The question that was posed was whether pigeons encode all or only a part of the stimulus array as landmarks for locating the goal. The results of tests in which

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individual landmarks were removed or shifted indicated that encoding was selective. That is, pigeons typically showed control by only a subset of the stimulus array. This finding was consistent across the three studies, despite the fact that they differed considerably in the type and arrangement of visual stimuli that were provided as possible landmarks. In Spetch and Mondloch's study, four distinct graphic stimuli surrounded the goal, and each landmark was close to the goal. In Spetch and Wilkie's study, the stimulus display consisted of digitized images of three landmark objects (a potted tree, potted flowers, and a log) on a grassy field. The three landmarks differed substantially in distance to the goal. In Cheng and Spetch's study, the stimuli consisted of a small graphic symbol near the goal and a large graphic frame surrounding the goal (with one edge of the frame close to the goal). Pigeons did not show evidence of encoding all of the available stimuli for use in locating the goal in any of these studies.

Given that pigeons do not use all of the available landmark information, a question that emerges is what factors determine the amount of control acquired by a given landmark. The results of Spetch and Wilkie's (1994) study indicated that one important factor is the absolute proximity to the goal. Spetch and Wilkie trained two groups of pigeons with the identical array of three landmarks, but the goal was in a different location with respect to the landmarks for each group, so that the landmark closest to the goal differed between groups. Test results indicated that the hierarchy of landmark control differed significantly between the two groups, with the nearest landmark to the goal acquiring the most control. This result is consistent with Cheng's (1989) finding that pigeons show greater control by a landmark near the goal than by a landmark far from the goal in the laboratory open-field task. Insects also appear to weight landmarks near the goal more heavily than landmarks far from the goal (e.g., Cheng, Collett, Pickard, & Wehner, 1987). Thus, absolute proximity to the goal appears to be a generally important determinant of landmark effectiveness, perhaps because nearer landmarks provide more precise spatial information. Specifically, given that Weber's law holds for spatial distances (Cheng, 1992), the variability of distance estimates is smaller for near landmarks than for far ones. In addition, the directional precision needed to localize the goal from a particular point increases as a function of distance, making it more difficult to achieve an accurate search on the basis of a single, distant landmark than on the basis of a single, near landmark.

Absolute proximity to the goal, however, does not explain all selectivity of landmark control. In Spetch and Mondloch's (1993) study, selective control by only one or two out of four landmarks emerged even though all landmarks were reasonably close to the goal. None of the pigeons showed good control at the most distant landmark from the goal, but they did not consistently show highest control at the nearest landmark. Even for birds trained with the identical arrangement of landmarks, control by the three nearest landmarks varied across birds but was consistent across tests within each bird. In other words, pigeons showed a stable, but individual, hierarchy of landmark control. Individual pat-

terns of selective control also appeared when the stimulus display consisted of a localized graphic stimulus and a graphic frame (Cheng & Spetch, *in press*). In that case, 2 pigeons showed exclusive control by the localized landmark, 3 pigeons showed primary control by the landmark and showed some control by the frame, and 1 pigeon showed primary control by the frame. Again, the pattern of control, although differing across pigeons, was highly consistent across tests within each pigeon.

The idiosyncratic patterns of selective landmark control seen by Spetch and Mondloch (1993) and by Cheng and Spetch (*in press*) are reminiscent of the visual attention results reported by Reynolds in 1961. He trained 2 pigeons in an operant discrimination task in which one compound stimulus (a triangle on a red background) signaled a reinforcement schedule, whereas another compound stimulus (a circle on a green background) signaled an extinction schedule. During tests in which he presented the color elements and shape elements alone, he found that one pigeon responded only to the red element, whereas the other pigeon responded only to the triangle element. Reynolds suggested that "pigeons may attend to only one of several aspects of a discriminative stimulus" (p. 208). The results reported by Spetch and Mondloch and Cheng and Spetch are suggestive of a similar attention effect in spatial landmark learning.

One interpretation of idiosyncratic control is that stimuli may compete for control, so that the control acquired by one element of a compound stimulus detracts from the control acquired by other elements. In associative terminology, the stimulus element attended to overshadows the remaining elements. This interpretation assumes that each subject is capable of learning about each of the elements and would do so if the overshadowing element were not present during training. The standard procedure for demonstrating overshadowing includes the control condition necessary to test this assumption. Specifically, a comparison is made between the control that is acquired by a stimulus when it is presented both with and without the overshadowing stimulus during acquisition. Such designs have been used to demonstrate overshadowing in classical and instrumental procedures (e.g., see Mackintosh, 1974).

The extent to which an overshadowing effect might also occur in visual landmark learning has not been systematically addressed, although there is evidence that overshadowing can occur in certain kinds of spatial tasks. Specifically, in studies of spatial learning in rats using the radial maze, Chamizo, Sterio, and Mackintosh (1985) and March, Chamizo, and Mackintosh (1992) provided evidence that overshadowing occurs between intramaze and extramaze cues. To date, however, it has not been demonstrated that overshadowing occurs among similar types of landmarks (i.e., among local visual landmarks) in a task in which the landmarks are used to pinpoint a single goal within an otherwise undifferentiated spatial arena.

The purpose of the current research was to demonstrate an overshadowing effect in the touch-screen spatial search task. Specifically, the experiments were designed to test the hypothesis that the control acquired by a given local landmark depends not only on its absolute characteristics (e.g.,

its absolute proximity to the goal) but also on its relative properties (e.g., whether it is the closest landmark to the goal). This hypothesis was tested with pigeons (Experiment 1) and with human participants (Experiments 2–4), by using a within-subject version of the overshadowing design.

Experiment 1

In this experiment, a within-subject design was used to compare the control of spatial searching that was acquired by two landmarks that were equally distant from the goal. One of these landmarks (Ov) was expected to be overshadowed, because during training it always appeared with two other landmarks, one of which was closer to the goal. The comparison landmark (NonOv) was not expected to be overshadowed, because during training it appeared with only one other landmark, which was farther from the goal. Two groups of pigeons provided counterbalancing of stimulus features and landmark direction in the Ov and NonOv landmarks. After the training sessions, control by the Ov and NonOv landmarks was compared during nonreinforced probe tests in which each landmark was presented alone or in which both landmarks were presented together but in shifted locations.

Method

Subjects

The subjects were six adult silver king pigeons that had previously served in a timing experiment in standard operant-conditioning chambers but were naive with respect to the spatial search task and the touch-screen chamber. All birds were housed in large individual cages under a 12-hr light/dark cycle (lights on at 6:00 a.m.). The birds were maintained at approximately 85% of their free-feeding weights by mixed grain obtained during and after the experimental sessions. Water and grit were available ad libitum in the home cages.

Apparatus

The experimental chamber was a modified BRS/LVE operant chamber equipped with a color monitor (Zenith 1492) and an infrared touch-frame (Carroll Touch, 1492 Smart Frame). A 28-cm by 20-cm monitor opening was cut into the back wall of the chamber, 9 cm above the floor. A thin sheet of Plexiglas covered the monitor screen, and spacers were used to recess the touch-frame by approximately 3 cm from the monitor opening and to separate the frame from the monitor by approximately 1.5 cm. The chamber contained two BRS/LVE grain hoppers, one on each of the side walls, 8 cm from the back wall and 9 cm from the floor. Lamps located within each feeder were used to illuminate feeder presentations. Photocells in each hopper measured head entries into the hopper.

A microcomputer located in an adjacent room controlled experimental contingencies, presented stimulus displays, operated feeders, and recorded peck coordinates. The touch-frame was programmed to detect individual pecks (i.e., detection of a beam break, then a return to unbroken beams before another peck would be recorded).

Search Space and Stimuli

The search space consisted of the illuminated surface of the color monitor, which formed a rectangular area of approximately 25 cm by 19 cm. Because the pigeons were free to move about in the chamber, the stimulus display could be viewed from a distance up to approximately 40 cm, although casual observation suggested that the pigeons typically viewed the screen from less than 20 cm prior to pecking. The landmarks consisted of four small graphic stimuli (see Figure 1) that differed in both shape and color (the star was green, the pie was blue, the ellipse was light red, and the rectangle was brown). The monitor was always illuminated with a dark gray background color. The goal was an area of approximately 2 cm² that was undifferentiated from the background except during initial training (the outline of the goal is shown in Figure 1 for illustrative purposes only). The top two diagrams in Figure 1 show the landmark arrangements of the two types of baseline-training trials presented to Group A, and the bottom two diagrams show the landmark arrangements of the two types of baseline-training trials presented to Group B. During training, each landmark maintained a fixed spatial relationship to the goal whenever the landmark was present (i.e., its distance and direction from the goal did not vary), and the landmark array maintained a fixed

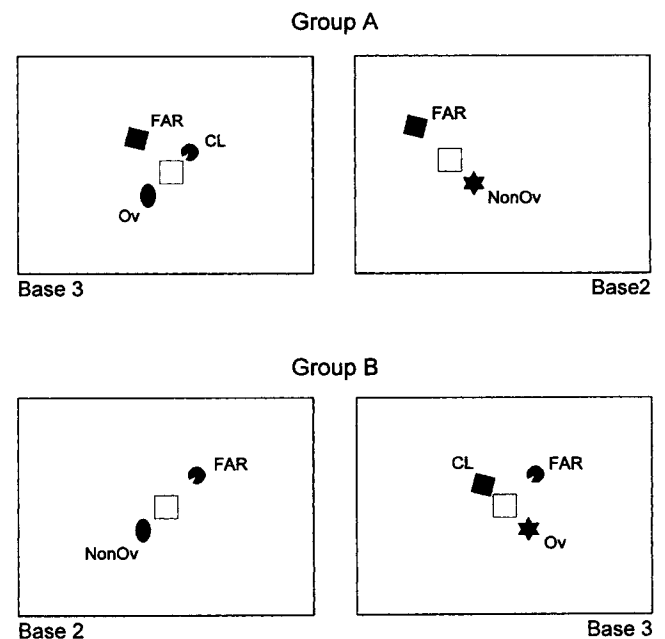


Figure 1. Diagram (drawn to scale) of the search space and stimulus arrangements used in Experiments 1 and 2. The search space was approximately 25 cm by 19 cm. The arrangements of landmarks and the goal used for the two baseline-trial types (Base 2 and Base 3) are shown in the two top diagrams for Group A, and in the two bottom diagrams for Group B. In each diagram, the outlined square indicates the 2-cm² goal (which was always unmarked except during preliminary training), and the filled symbols are the graphic landmarks. Each landmark was a distinct color (star = green, pie = blue, ellipse = light red, and rectangle = brown). The screen location of the goal and landmark array varied across trials. CL = close landmark, FAR = far landmark, OV = landmark expected to be overshadowed, NonOv = landmark expected not to be overshadowed.

orientation on the screen (i.e., the landmarks were not rotated). However, the locations on the screen of the entire array of landmarks and corresponding goal area was varied from trial to trial. During each baseline-training trial, the location of the center of the goal on the screen was randomly selected with three constraints. First, the goal was placed only in locations that allowed room for all landmarks. Second, I did not use the lowest two goal locations that were possible, given the first constraint, because past research has indicated that some birds have difficulty pecking accurately at targets low on the screen. Finally, to ensure that the goal area always contained the same number of possible response coordinates, the center of the goal was always placed midway between two infrared beams in both dimensions. This resulted in 180 possible locations for the goal center. During control and test trials, a more restricted range of goal locations was used to ensure that there was at least 2.5 cm of search space on all sides of each landmark.

General Procedures

Sessions were conducted at approximately the same time each day, 5 or 6 days per week. Sessions lasted until all scheduled trials were completed or for a maximum of 1 hr. The monitor screen was cleaned with window cleaner at the beginning of each day and between sessions as needed.

Preliminary Training

Each bird was initially trained to eat from the food hoppers and then was given several sessions of autoshaping. Each autoshaping trial began with illumination of a solid, 2-cm yellow square that marked the goal against the dark gray background. The location of the goal and its marker varied across trials as described above. The goal marker remained illuminated for 8 s or until a peck in the goal area was recorded; a food reward was then presented (2 s of eating time from a randomly selected food hopper). Trials were separated by a 60-s intertrial interval (ITI), during which the monitor was illuminated only with the dark gray background. Once a pigeon pecked on at least 80% of the trials in a session, the ITI was reduced to 5 s, and the procedure was changed so that a peck in the goal area was required to terminate the trial and produce the food reward. This peck training continued until a pigeon successfully completed at least 80 trials in a session.

Search Training

During this stage of training, pigeons were gradually trained to find the goal using landmarks rather than using the marker. First, the graphic landmarks were introduced with the goal marker still present. For each group, a randomly selected half of the trials in each trial block contained the landmark set shown as Base 2, and the remaining trials contained the landmark set shown as Base 3 (see Figure 1). Following the successful completion of at least 80 trials in a session, the pigeon received a series of sessions in which the goal marker was faded out within and between sessions by gradually changing the graphic fill pattern from solid to empty at a rate that depended on the bird's accuracy. This training phase continued until the bird completed at least 80 trials in a session with the goal marker absent.

During the next phase of training, the response requirement was gradually increased over sessions. First, the number of pecks required to the goal area was increased from one to three pecks.

Then, a consecutive-peck requirement was added so that the last two pecks had to be in the goal area. Pecks outside the goal area reset the consecutive-peck counter. This requirement ensured that the bird could not trigger reinforcement by sweeping its beak around in the general vicinity of the goal. Each increment in the response requirement was implemented only if the bird completed 80 trials in a session.

During a final phase of training, the density of reinforcement for meeting the response requirement was decreased from 100% to 80% and finally from 80% to 50% in preparation for testing. The density of reinforcement was always equated for Base 2 and Base 3 trials within each block of trials in a session. On nonreinforced trials, completion of the response criteria resulted in initiation of the ITI. Thus, by the end of training all birds were accustomed to responding to the goal area several times in each trial and to receiving food reinforcement only 50% of the time that they met the response criteria. Each bird remained on the baseline 50%-reinforcement condition for a minimum of 5 sessions and advanced to the test phase only after it completed at least 80 trials on each of the last two sessions.

During all search-training sessions, Base 2 and Base 3 trials were presented equally as often in a randomly determined order in each block of 10 trials. The search-training phase required between 12 and 39 sessions.

Testing

The purpose of the test phase was to determine how much control of searching had been acquired by the bottom two landmarks in each group. As can be seen in Figure 1, these two landmarks are approximately equal in distance from the goal within each group, and they are identical across groups. However, they differ in their *relative* proximity to the goal. During training, one of the bottom landmarks (labeled *Ov*) was always presented together with two other landmarks, one of which was closer to the goal. The other bottom landmark (labeled *NonOv*) was presented only with the more distant landmark during training. Landmark *Ov* should therefore have been subject to more overshadowing than landmark *NonOv* and should consequently have acquired less control of search behavior. Although my focus was on the control acquired by landmarks *Ov* and *NonOv*, I also included some tests with the two top landmarks to compare control by the closer landmark (*CL*) with control by the far, but always available, landmark (*FAR*). It should be noted that stimulus characteristics were not balanced between the top and bottom landmarks. Thus, meaningful comparisons can be made within the top pair and within the bottom pair of landmarks, but not between the top and bottom landmarks.

All test sessions consisted of a mixture of (a) reinforced and nonreinforced Base 2 and Base 3 trials, (b) control trials that were visually identical to Base 2 and Base 3 trials but terminated in the same way as test trials (described below), and (c) test trials. On both control and test trials, the trial terminated without reinforcement 8 s after the second peck recorded anywhere on the screen. Each bird received three types of test sessions (described below). One of each type of test session was presented in each three-session block, with the order varying randomly among blocks. Four blocks of test sessions were presented, each separated by one baseline-training session.

Single landmark tests. During these tests, each landmark was presented alone in order to assess the extent to which the landmark could support accurate search when no other landmarks were present. Each block of trials included a single landmark test with each of the four landmarks.

Bottom-pair tests. These tests were conducted to assess the relative weight given to landmark Ov and NonOv when they were presented together but in shifted positions. Each block of trials included five types of tests. During bottom-pair unshifted tests, landmarks Ov and NonOv were presented together in locations that were consistent with a single hypothetical goal (hypothetical because reinforcement was never available on test trials). Specifically, the goal location was selected, and then each landmark was placed in its training position relative to that goal. These tests were designed to provide a comparison for the tests (described below) in which the location of one of the landmarks was shifted. During bottom-pair, horizontal-shift tests, landmarks Ov and NonOv were presented together but in horizontally shifted locations. In this case, the goal location was selected, and then each landmark was placed in a location that was shifted horizontally by one unit (approximately 1 cm) away from its training position relative to the goal. Thus, the landmarks were spread out in the horizontal dimension relative to the unshifted tests. In two other types of tests, the bottom pair of landmarks was presented together with one landmark shifted vertically by two units (approximately 2 cm) down from its unshifted position. Finally, during bottom-pair swapped tests, the bottom landmarks were presented together, but their positions were interchanged (i.e., the ellipse was on the right and the star was on the left). In this case, the hypothetical goal in relation to each landmark was on opposite sides of the landmark array.

Top-pair tests. These tests were conducted to determine the relative weight given to each of the two top landmarks. Each block of trials included three types of test trials. During top-pair unshifted tests, which provided a comparison for the shift tests, the top two landmarks were presented in their normal positions with respect to the goal. During top-pair, horizontal-shift tests, the two top landmarks were placed in positions that were each shifted horizontally one unit away from the goal. Finally, during top-pair swapped tests, the top two landmarks were presented together with their positions interchanged.

Data Recording and Analysis

Peck coordinates were recorded in units that were approximately 1 cm². For each trial, this resulted in a 25 by 18 unit matrix. All trials of each type were combined across all test sessions. For each bird, accuracy scores were computed by determining the proportion of total pecks that fell in the four units that made up the goal location. For swap tests, I calculated two accuracy scores, one based on the proportion of pecks that fell in the hypothetical goal area relative to each landmark. Note that the probability of responding within the goal area on the basis of chance is very low. On each reinforced trial, the goal was centered at the top left edge of any of 18 horizontal units and 10 vertical units. Because the goal extended one unit above and one unit to the left of this center point, there were 19 horizontal units and 11 vertical units (for a product of 209 units) that could serve as reinforced goal areas. If a bird responded randomly in these 209 units, the proportion of pecks expected to fall within the 4 units that contained the goal on a given trial was only .019.

To examine the spatial distribution of responses, the responses from all tests of a given type were collapsed into a single response distribution. Because the goal location varied across trials, units were defined relative to the goal. The variable location of the goal on the screen meant that response units far from the goal were not available on all trials (e.g., units far to the left of the goal were available only when the goal was located on the right side of the

screen). To adjust for this differential availability of response units, the data were weighted by dividing the number of responses in each unit by the number of trials in which the unit was available. For the landmark-shift tests, these weighted response distributions were used to derive the peak places of searching in the horizontal and vertical dimensions. These peaks were calculated using the iterated median procedure as described in Cheng (1989) and Spetch et al. (1992).

Results

Analyses of variance (ANOVAs) on each of the measures indicated that there was no significant difference between the two groups and that the group variable did not interact significantly with any other variable. The data from the two groups were therefore combined and, except where otherwise noted, comparisons were made using within-subject *t* tests. For comparisons between landmark Ov and landmark NonOv, in which I predicted a priori that landmark Ov would show less control than landmark NonOv, my criterion for statistical significance was $p < .05$, one-tailed; for all other comparisons, my criterion for statistical significance was $p < .05$, two-tailed.

Control-Trial Accuracy

Accuracy was slightly higher on control trials involving three landmarks ($M = .535$) than on control trials with two landmarks ($M = .483$), but this difference was not statistically significant, $t(5) = 1.65$.

Landmarks Ov and NonOv

The various types of tests that were presented gave me four measures of the relative control acquired by landmark Ov versus landmark NonOv. All of these measures indicated that landmark NonOv had acquired more control than landmark Ov (see Figure 2). First, the single landmark tests revealed significantly higher accuracy when landmark NonOv was presented alone than when landmark Ov was presented alone, $t(5) = 2.33$. Second, when the two landmarks were presented together but their positions were interchanged, the proportion of pecks that fell in the hypothetical goal area for landmark NonOv was significantly higher than the proportion of pecks that fell in the hypothetical goal area for landmark Ov, $t(5) = 2.18$. Third, on the vertical-shift tests with each landmark, the shift in the vertical peak place of searching (relative to tests in which the two landmarks were presented together in unshifted positions) was greater for landmark NonOv than for landmark Ov, $t(5) = 3.96$. Finally, when the landmarks were presented together but were spread out horizontally, the peak place of searching was shifted toward landmark NonOv; this was relative to test trials in which the landmarks were presented together in unshifted positions. This shift toward landmark NonOv was significantly greater than zero according to a one-sample *t* test, $t(5) = 4.20$. Thus, as predicted on the basis of overshadowing, landmark Ov acquired less control of searching than landmark NonOv.

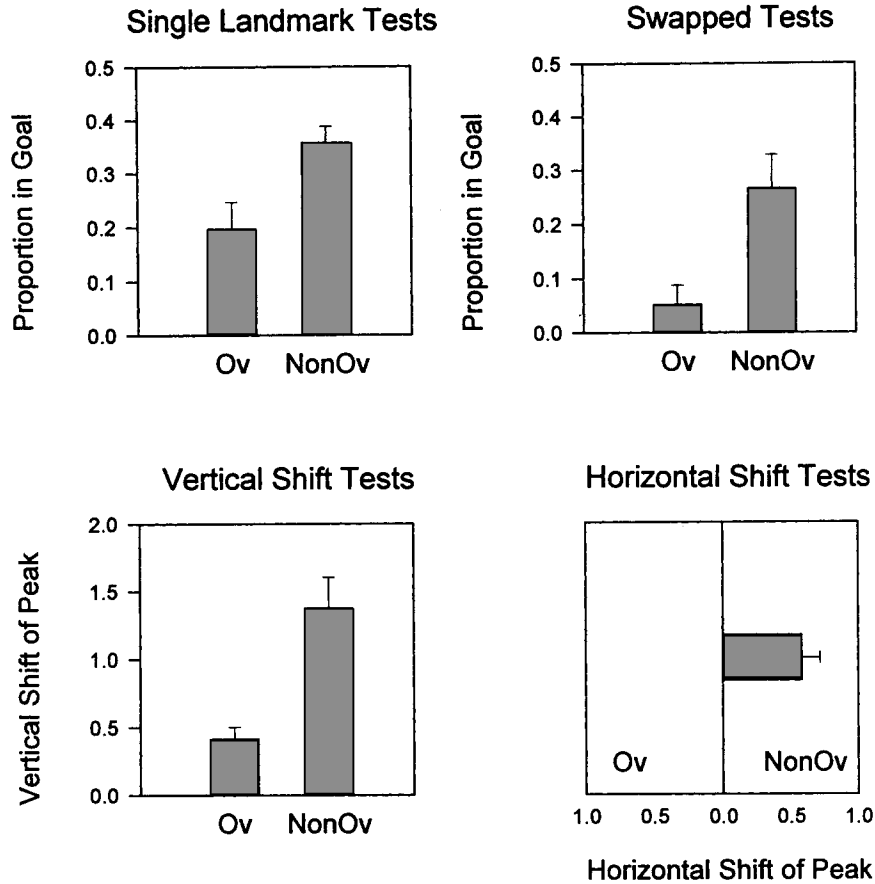


Figure 2. Results of four tests comparing control by the landmark that was expected to be overshadowed (Ov) and the landmark that was not expected to be overshadowed (NonOv) for pigeons in Experiment 1. The top left graph shows the proportion of total pecks that fell in the 2-cm² hypothetical goal area on test trials in which each landmark was presented alone. The top right graph shows the proportion of pecks that fell in the hypothetical goal area that would be specified by each landmark on test trials in which the landmarks were presented together but with their positions interchanged. The bottom left graph shows the shift in the calculated vertical peak place of searching on test trials in which landmarks Ov and NonOv were presented together, but one of them was shifted vertically by 2 units (approximately 2 cm). The y-axis plots the magnitude (in units) of the shift in peak place in searching toward the shifted landmark. The x-axis indicates which landmark was shifted. The bottom right graph shows the shift in calculated horizontal peak place of searching on test trials in which landmarks Ov and NonOv were presented together but were each shifted horizontally by one unit away from each other. The x-axis shows the magnitude (in units) of the shift in peak place, with values to the left of 0 indicating a shift toward landmark Ov and values to the right of 0 indicating a shift toward landmark NonOv.

Inspection of the response distributions for the single landmark tests suggests that responding was typically more localized for landmark NonOv than for landmark Ov. Figure 3 plots the response distributions on the single landmark tests with landmark NonOv and landmark Ov for two representative birds (accuracy scores for Bird 45 were higher than the mean for both NonOv [.481] and Ov [.244] single landmark tests, whereas the scores for Bird 67 were slightly lower than the mean for both NonOv [.325] and Ov [.176] single landmark tests). The height of each distribution indicates the proportion of weighted pecks falling in each unit. Units containing less than .001 of the weighted pecks are

plotted as empty units. Each graph shows eight units (approximately 8 cm) on either side of center of the hypothetical goal, which is indicated by the intersection of the two zero lines.

Top Landmarks

In general, the tests conducted with the top landmarks suggest that the CL landmark acquired somewhat more control than the FAR landmark. When each landmark was presented alone, accuracy was higher for landmark CL

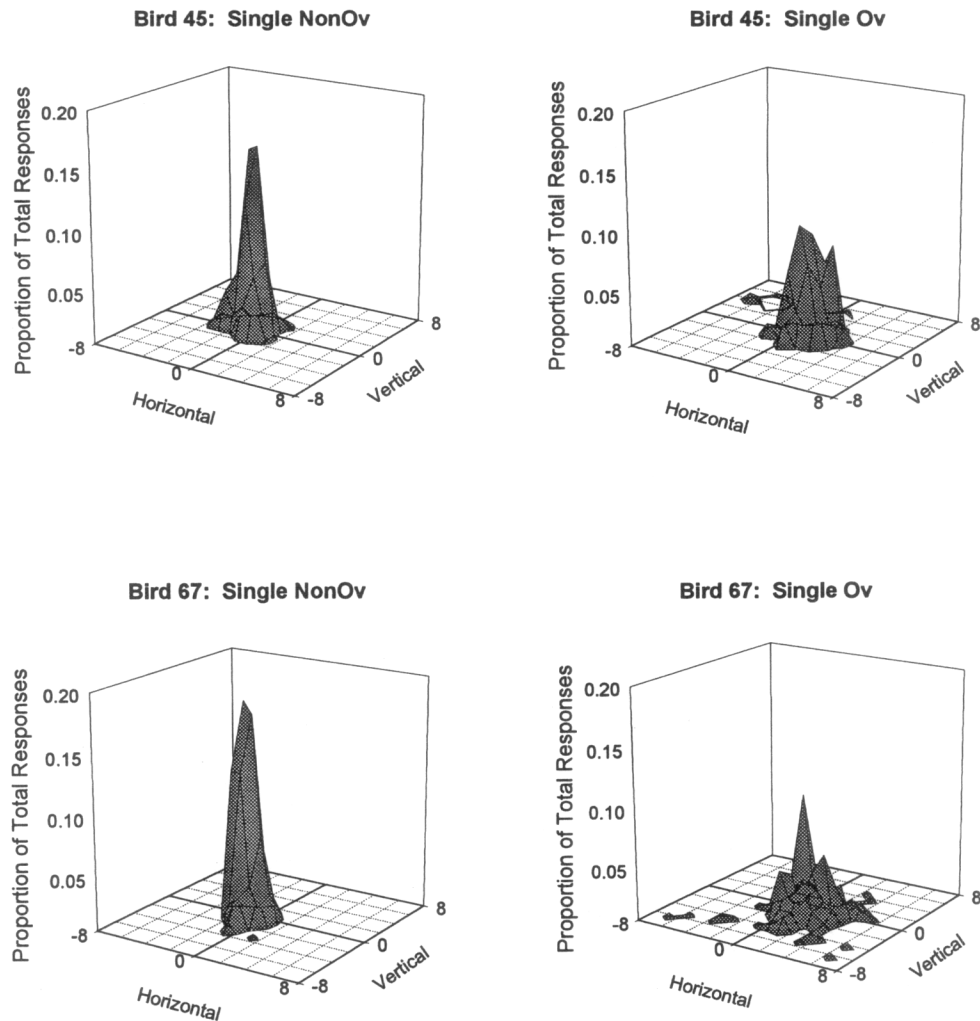


Figure 3. Response distributions of 2 birds on single landmark tests with landmark NonOv and landmark Ov in Experiment 1. NonOv = landmark expected not to be overshadowed; Ov = landmark expected to be overshadowed.

($M = .138$) than for landmark FAR ($M = .028$), but this difference was not significant, $t(5) = 1.84$. When the two landmarks were presented together but their positions were interchanged, pigeons made more responses in the hypothetical goal according to the CL landmark ($M = .137$) than in the hypothetical goal according to the FAR landmark ($M = .013$); however, this difference just failed to reach significance according to a two-tailed test, $t(5) = 2.31$. When the top landmarks were presented together and each was shifted by one unit horizontally away from the goal, the peak of searching shifted by .558 of a unit toward landmark CL relative to test trials in which they were not shifted. This shift toward landmark CL was significant, $t(5) = 8.93$.

Discussion

The hypothesis that landmark control would be subject to overshadowing was clearly supported. Pigeons acquired

more control by a landmark that was the closest of those present to the goal than by a comparable landmark that was not the closest landmark of its set to the goal. The difference in control by landmarks Ov and NonOv cannot be attributed to the physical features of the landmark, the absolute proximity to the goal, or the direction from the goal, because these variables were exactly counterbalanced across subjects in the two groups. Thus, the control acquired by a given landmark does not depend exclusively on its absolute properties but also depends on the presence of other landmarks.

Experiment 2

Many basic principles of learning have been found to occur in a wide range of species. If overshadowing of landmark control is a general characteristic of landmark learning, this overshadowing may be evident in the search

behavior of diverse species. The touch-screen task provides an ideal tool for comparative studies of landmark learning because the same stimulus displays used for pigeons can also be presented to other organisms, including humans. Experiment 2 sought to assess the species generality of the overshadowing effect seen in Experiment 1, by testing human participants with the identical stimulus displays used for the pigeons. The procedure used for the human participants was similar to that used for the pigeons except that human participants (a) touched the screen with a stylus, (b) received points as the reinforcement for correct responses, and (c) completed training and testing within a single 45-min session (to accommodate this shorter time frame, human participants received fewer kinds of tests than the pigeons in Experiment 1).

Method

Participants

The subjects were 6 undergraduate students who participated in the experiment for participation credit in their introductory psychology course. All participants were between 18 and 20 years of age. They were assigned to groups according to their order of participation in the experiment. The group assignment for the first participant was determined randomly, and group assignments were alternated for the remaining participants. Both groups were composed of 2 women and 1 man.

Apparatus

The experiment took place in a small private room that contained a touch-screen-equipped computer. The computer monitor (Zenith 1490) and touch-screen (Carroll Touch 1490 Smart Frame) provided the same search space and stimuli as used for the pigeons in Experiment 1. Participants sat in a chair in front of the monitor and searched by touching the screen with a stylus (the eraser end of a pencil). The distance from which participants viewed the display varied depending on how they sat in the chair, but the typical viewing distance was estimated to be 45 cm.

Procedure

The stimulus arrangements for Groups A and B were the same as used for the pigeons in Experiment 1. Participants in each group were trained with the same pair of trial types as shown in Figure 1.

At the beginning of each session, participants were provided with the following information: Their task would be to remember and locate a goal area, which would be marked on initial trials but thereafter would be unmarked. Points would be available on some randomly selected trials. They could obtain a point only if they correctly located the goal and touched it a certain number of times. The required number of touches to the goal would vary across trials, and sometimes they would be required to touch the goal more than once in a row to earn the point. Whenever they earned a point, a message would appear to display their cumulative number of points. When points were not available, the trial would end without a point, regardless of whether they were correct. The session would end after they obtained a certain number of points or

after 45 min, whichever came first. Their results would be stored in a numbered file that did not contain their identity.

The experimenter then ran a demonstration program and told participants that at the beginning of their session they would be asked to enter their age by touching the appropriate numbers and their gender by touching M (male) or F (female). While demonstrating how to input these data, the experimenter explained that touches were recorded with a grid of infrared beams, so it was important to hold the pencil straight and to remove the pencil from the beams between touches. Participants were then presented with four demonstration trials. During the first two trials, the goal was marked with a rectangle that outlined its area. One of these trials presented three landmarks (Base 3) and the other trial presented two landmarks (Base 2). The last two demonstration trials consisted of one of each trial type but with the goal marker absent. During each trial, the location on the screen of the goal and the corresponding landmark array was selected randomly, as described in Experiment 1. The participant was given the pencil to practice touching the goal during the four demonstration trials. During each of the four demonstration trials, two touches in the goal were required to complete the trial. Each trial ended as a reinforced trial in which a point was earned (i.e., the screen was blanked and then a cumulative point display was presented). Any procedural questions posed by the participant were answered with the statement, "I'm sorry but I cannot provide any further information until after you have completed the experiment." After obtaining confirmation that the participant still wished to participate, the experimenter then started the program for the participant and left the room.

The participant's program began in the same manner as the demonstration program; that is, participants were first asked to input their age and gender and then a series of trials were presented, the first four of which were identical to those provided during the demonstration. During the last two of these trials and all subsequent trials, the goal was unmarked. During the next four trials (two of each type), the response requirement was set at three touches in the goal, and reinforcement (i.e., a point) was presented after each trial. For the next four trials (two of each type) and all subsequent training trials, a variable response requirement was used: To complete a trial the participant was required to complete either zero, one, or two initial touches in the goal followed by either one, two, or three consecutive-goal touches. Thus, the minimum number of correct touches required to complete a trial varied from one to five. On trials requiring two or three consecutive touches, the actual number of correct touches could exceed this minimum because each touch outside of the goal reset the consecutive-touch counter. For Trials 12–36, only 50% of the trials were reinforced. Each block of 8 trials contained two reinforced and two nonreinforced trials of each type presented in a randomly determined order. On nonreinforced trials, the screen went blank for 2 s after completion of the response requirement, but no message was presented and the point counter was not incremented.

The remaining trials of the session consisted of a mixture of (a) reinforced and nonreinforced training trials of each type, (b) control trials that were visually identical to Base 2 and Base 3 trials, and (c) test trials. During control and test trials, the second touch recorded anywhere on the screen initiated an interval that varied randomly from 2 s to 4 s, after which the first response anywhere on the screen terminated the trial. Each block of 20 trials contained 5 reinforced, 1 nonreinforced, and 1 control trial of each type, as well as 6 test trials. Four of these test trials were single landmark tests, one with each of the four landmarks. One test was a bottom-pair swapped test in which the bottom two landmarks were presented together but with their positions interchanged, and the final test was a top-pair swapped test in which the top two landmarks

were presented together with their positions interchanged. Participants received a total of 5 trials of each type of test.

Data were recorded, summarized, and analyzed in the same way as described in Experiment 1. Participants were fully debriefed following completion of the session, and any questions they posed were answered.

Results

ANOVAs on each of the measures indicated that there was no significant difference between the groups and that the group variable did not interact significantly with any other variable. The data from the two groups were therefore combined and comparisons were made using within-subject *t* tests. For comparisons between landmark Ov and landmark NonOv, in which I predicted a priori that landmark Ov would show less control than landmark NonOv, my criterion for statistical significance was $p < .05$, one-tailed; for all other comparisons, my criterion for statistical significance was $p < .05$, two-tailed.

Control Trials

Accuracy on the two types of control trials did not differ significantly (type Base 2, $M = .733$; type Base 3, $M = .738$), $t(5) = 0.151$.

Test Trials

The results of both the single landmark tests and the bottom-pair swap tests indicate that landmark NonOv acquired more control of searching than landmark Ov (see Figure 4). During the single landmark tests, accuracy was significantly higher on test trials in which landmark NonOv was presented alone than on test trials in which landmark Ov was presented alone, $t(5) = 4.30$. During the swap tests with the bottom two landmarks, participants made more touches in the hypothetical goal according to landmark NonOv than to the hypothetical goal according to landmark Ov, $t(5) = 3.08$.

The results of both the single landmark and the top-pair swap tests suggest that landmark CL acquired somewhat more control than landmark FAR, but the difference failed to reach statistical significance during either test. During single landmark tests, accuracy on tests with landmark CL ($M = .487$) was not significantly higher than on tests with landmark FAR ($M = .361$), $t(5) = 1.09$. During swap tests with the top landmarks, participants made more touches in the goal according to landmark CL ($M = .193$) than in the goal according to the landmark FAR ($M = .027$), but this difference just failed to reach significance, $t(5) = 2.21$.

Discussion

Despite the compressed training period and the higher levels of baseline accuracy achieved by the human participants, the similarity of their results to those seen with pigeons in Experiment 1 is striking. Both humans and

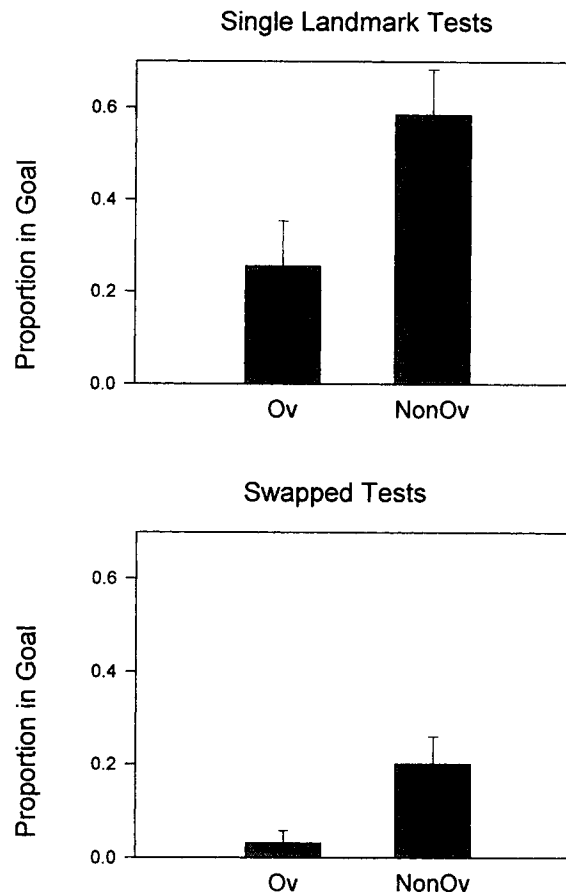


Figure 4. Results of two tests comparing control by the landmark expected to be overshadowed (Ov) and the landmark expected not to be overshadowed (NonOv) for human participants in Experiment 2. The top graph shows the proportion of total touches that fell in the 2-cm² hypothetical goal area on test trials in which each landmark was presented alone. The bottom graph shows the proportion of touches that fell in the hypothetical goal area that would be specified by each landmark on test trials in which they were presented together but with their positions interchanged.

pigeons learned more about a landmark when it occurred only with a more distant landmark than when it occurred with two other landmarks, one of which was closer to the goal. Thus, the effectiveness of a given stimulus as a landmark is determined not only by its absolute properties, but also by the presence of other landmarks.

Experiment 3

Experiments 1 and 2 revealed that control by a given landmark can be overshadowed by other landmarks, but it is not clear whether the overshadowed landmark gained less control because it occurred with a landmark that was closer to the goal or because it occurred with two other landmarks. Experiment 3 was designed to replicate Experiment 2 using a design in which relative proximity to the goal was the only variable that differed between the landmark that should be

overshadowed and the landmark that should not be overshadowed. Specifically, landmark Ov was presented in compound with landmark CL that was closer to the goal and landmark NonOv was presented in compound with landmark FAR that was farther from the goal. I predicted that landmark NonOv would acquire more control than landmark Ov and that landmark CL would acquire more control than landmark FAR.

Method

Participants

The participants were 8 undergraduate students who participated in the experiment for participation credit in their introductory psychology course. All participants were between 18 and 22 years of age. They were assigned to groups according to their order of participation in the experiment. The group assignment for the first participant was determined randomly, and group assignments were alternated for the remaining participants. Group A was composed of 4 women, and Group B was composed of 2 women and 2 men.

Apparatus

The apparatus was identical to that used in Experiment 2. The search space and stimuli were similar except that each of the two training trial types (Base CL and Base FAR) consisted of only two stimuli, as shown in Figure 5.

Procedure

All aspects of the procedure were identical to those described in Experiment 2.

Results

ANOVAs on each of the measures indicated that there was no significant difference between the two groups and that the group variable did not interact significantly with any other variable. The data from the two groups were therefore combined, and comparisons were made using within-subject *t* tests. For comparisons between landmarks Ov and NonOv and between landmarks CL and FAR, for which a priori predictions of directional differences were made, the criterion for statistical significance was $p < .05$, one-tailed. For comparisons between the two types of control trials, the criterion for statistical significance was $p < .05$, two-tailed.

Control Trials

Accuracy on control trials of type Base CL ($M = .60$) did not differ significantly from that on control trials of type Base FAR ($M = .61$), $t(7) = 0.17$.

Test Trials

During the single landmark tests (Figure 6), accuracy was significantly higher on test trials in which landmark NonOv

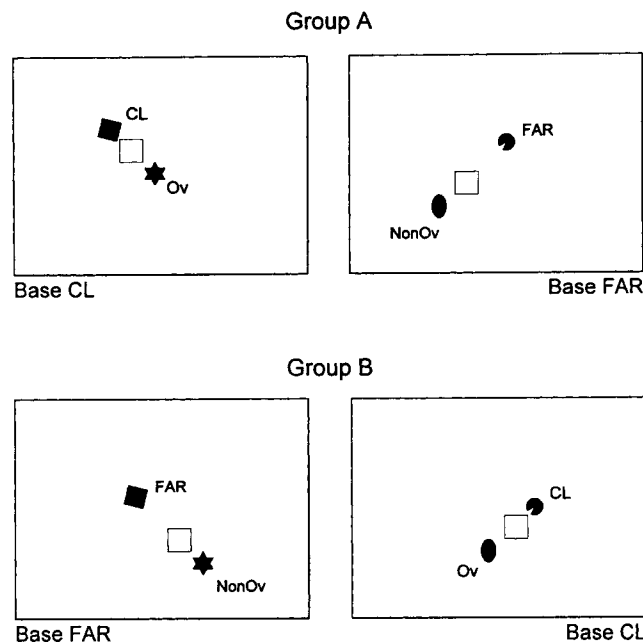


Figure 5. Diagram (drawn to scale) of the search space and stimulus arrangements used in Experiment 3. The search space was approximately 25 cm by 19 cm. The arrangements of landmarks and the goal used for the two baseline-trial types (Base CL and Base FAR) are shown in the two top diagrams for Group A and in the two bottom diagrams for Group B. In each diagram, the outlined square indicates the 2-cm² goal (which was always unmarked except during preliminary training), and the filled symbols are the graphic landmarks. Each landmark was a distinct color (star = green, pie = blue, ellipse = light red, and rectangle = brown). The screen location of the goal and landmark array varied across trials. CL = close landmark, FAR = far landmark, Ov = landmark expected to be overshadowed, and NonOv = landmark expected not to be overshadowed.

was presented alone than on test trials in which landmark Ov was presented alone, $t(7) = 2.517$. During the swap tests with the bottom two landmarks, participants made few touches in the hypothetical goal according to either landmark NonOv ($M = .089$) or landmark Ov ($M = .010$), and the difference between these failed to reach significance, $t(7) = 1.83$.

During single landmark tests with the top two landmarks, participants were somewhat more accurate on tests with landmark CL ($M = .239$) than on tests with landmark FAR ($M = .157$), but the difference was not significant, $t(7) = 1.11$. During swap tests with the top landmarks, participants made few touches in the goal according to either landmark CL ($M = .035$; FAR, $M = 0$), and the difference was not significant, $t(7) = 1.77$.

Discussion

In general, the results of this experiment suggest that relative proximity alone is sufficient to produce an overshadowing effect. Landmark NonOv exerted significantly

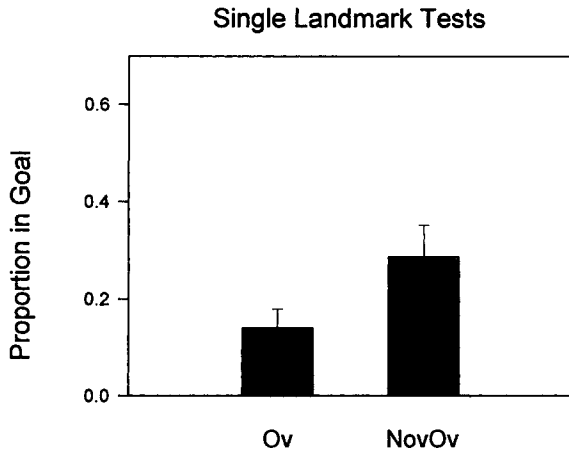


Figure 6. Proportion of total touches that fell in the 2-cm² hypothetical goal area on test trials in which the landmark expected to be overshadowed (Ov) and the landmark expected not to be overshadowed (NonOv) were presented alone for human participants in Experiment 3.

more control of accurate search than landmark Ov during the single landmark tests and showed a tendency toward greater control during the landmark swap tests.

One peculiar result of this study was that participants made so few responses in the hypothetical goals defined by either landmark during the swap tests. A closer inspection of the data suggests that participants may have adopted a strategy of "respond between the landmarks." For example, on bottom-landmark swap tests, the peak place of searching for most of the participants was approximately midway between the two landmarks in the horizontal dimension and was shifted downward from the hypothetical goal locations, so that it fell on the same vertical line as the landmarks. Thus, whenever two landmarks were present, the participants appeared to respond on the basis of a relational rule rather than on the basis of a learned distance and direction from the individual landmarks. A tendency to learn the task primarily on the basis of a relational rule may also account for the considerably lower accuracy seen on single landmark tests in this experiment compared with Experiment 2.

Experiment 4

The results of Experiment 3 support the hypothesis of overshadowing based on relative proximity, but the failure to find a significant effect on more than one measure is troublesome. Experiment 4 therefore replicated Experiment 3 but used more participants and a slightly different arrangement of stimuli. Specifically, to discourage the learning of a "between the landmarks" rule, the pairs of landmarks presented during training were arranged so that goal did not fall on a line between the landmarks (see Figure 7). This experiment also included additional tests to compare control by landmarks Ov and NonOv.

Method

Participants

The participants were 16 undergraduate students who participated in the experiment for participation credit in their introductory psychology course. Participants were between 17 and 36 years of age. They were assigned to groups according to their order of participation in the experiment. The group assignment for the first participant was determined randomly, and group assignments were alternated for the remaining participants. Group A was composed of 5 women and 3 men, and Group B was composed of 3 women and 5 men.

Apparatus

The apparatus was identical to that used in Experiment 2. The search space and stimuli were similar to that of Experiment 3 except for the arrangement of the stimuli (see Figure 7).

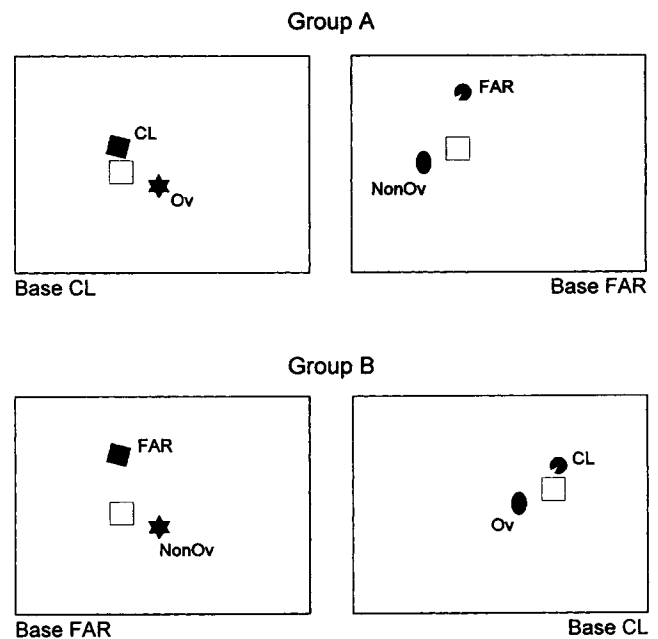


Figure 7. Diagram (drawn to scale) of the search space and stimulus arrangements used in Experiment 4. The search space was approximately 25 cm by 19 cm. The arrangements of landmarks and the goal used for the two baseline-trial types (Base CL and Base FAR) are shown in the two top diagrams for Group A and in the two bottom diagrams for Group B. In each diagram, the outlined square indicates the 2-cm² goal (which was always unmarked except during preliminary training), and the filled symbols are the graphic landmarks. Each landmark was a distinct color (star = green, pie = blue, ellipse = light red, and rectangle = brown). The screen location of the goal and landmark array varied across trials. CL = close landmark, FAR = far landmark, Ov = landmark expected to be overshadowed, and NonOv = landmark expected not to be overshadowed.

Procedure

All aspects of the procedure were identical to those described in Experiment 2 except for the types of test trials presented. In this experiment, participants received eight kinds of test trials in total. Four of these were single landmark tests in which each of the four landmarks was presented individually. The remaining tests entailed presentation of both of the bottom landmarks (i.e., landmarks Ov and NonOv) but in shifted positions so that the hypothetical goal according to each landmark was in a different place. For horizontal-shift tests, each of the bottom landmarks was shifted by one unit horizontally away from goal. For swap tests, the bottom two landmarks were presented together but their positions relative to the goal were interchanged. The other two tests were vertical-shift tests: On one of these, landmark Ov was shifted upward by two units, and on the other, landmark NonOv was shifted upward by two units. Each block of 20 trials during testing included 5 reinforced baseline trials and one control trial of each type (Base CL and of Base FAR) and one of each of the eight types of test trials.

Results

ANOVAs on each of the measures indicated that there was no significant difference between the two groups and that the group variable did not interact significantly with any other variable. The data from the two groups were therefore combined, and comparisons were made using within-subject *t* tests. For comparisons between landmarks Ov and NonOv and between landmarks CL and FAR, for which a priori predictions of directional differences were made, the criterion for statistical significance was $p < .05$, one-tailed. For comparisons between the two types of control trials, the criterion for statistical significance was $p < .05$, two-tailed.

Control Trials

Accuracy on control trials of type Base CL ($M = .794$) was somewhat higher than on control trials of type Base FAR ($M = .659$), but the difference just failed to reach significance according to a two-tailed test, $t(15) = 2.01$.

Test Trials

The results of the single landmark tests and the horizontal- and vertical-shift tests with landmarks NonOv and Ov are shown in Figure 8. During the single landmark tests, accuracy was significantly higher on test trials in which landmark NonOv was presented alone than on test trials in which landmark Ov was presented alone, $t(15) = 3.58$. On tests in which the bottom landmarks were both presented but their relative locations were shifted, participants responded less accurately according to either landmark. Nevertheless, the horizontal- and vertical-shift tests revealed significantly more control by landmark NonOv than by landmark Ov.¹ During the horizontal-shift tests, in which both bottom landmarks were shifted horizontally, participants made more touches in the hypothetical goal according to landmark NonOv than in the hypothetical goal accord-

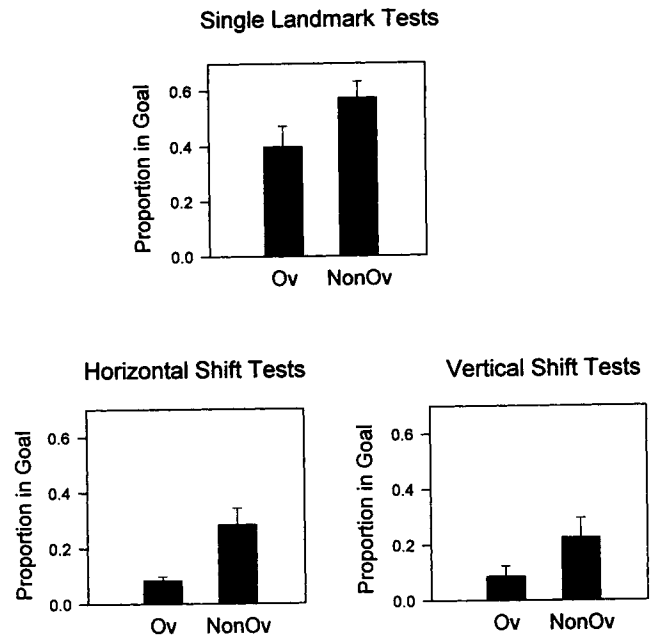


Figure 8. Results of three tests comparing control by the landmark expected to be overshadowed (Ov) and the landmark expected not to be overshadowed (NonOv) for human participants in Experiment 4. The top graph shows the proportion of total touches that fell in the 2-cm² hypothetical goal area on test trials in which each landmark was presented alone. The bottom left graph shows the proportion of touches that fell in the hypothetical goal area that would be specified by each landmark on test trials in which they were presented together but were each shifted horizontally by one unit away from each other. The bottom right graph shows the results of tests in which the two landmarks were presented together but one landmark was shifted up by 2 units. The data plotted are the proportion of pecks in the hypothetical goal according to landmark Ov when landmark Ov was shifted and the proportion of pecks in the hypothetical goal according to landmark NonOv when landmark NonOv was shifted.

ing to landmark Ov, $t(15) = 3.41$. During the vertical-shift tests, participants made more touches in the hypothetical goal according to landmark NonOv when landmark NonOv was shifted upward than in the hypothetical goal according to landmark Ov when landmark Ov was shifted upward, $t(15) = 2.03$. On the bottom-landmark swap tests, participants made more touches in the goal according to landmark

¹ The shift tests were assessed in terms of accuracy rather than peak place of searching (as in Experiment 1) because trials with the bottom landmarks in their normal locations were not included. Consequently, there was no comparison peak for assessing the degree of shift when the landmarks were shifted. However, analyses of absolute peak places were consistent with analyses of accuracy scores: During horizontal-shift tests, the peak was significantly shifted from the hypothetical goal center toward landmark NonOv (nonovershadowed), $t(15) = 2.61$, and during vertical-shift tests, the peak was significantly higher when landmark NonOv was shifted up than when landmark Ov (overshadowed) was shifted up, $t(15) = 2.08$.

NonOv ($M = .174$) than in the goal according to landmark Ov ($M = .074$), but this difference was not significant, $t(15) = 1.68$.

During single landmark tests with the top two landmarks, participants were significantly more accurate on tests with landmark CL ($M = .609$) than on tests with landmark FAR ($M = .395$), $t(15) = 2.26$.

Discussion

This experiment provided evidence that control of spatial search by a landmark can be overshadowed by the presence of a landmark that is closer to the goal. Thus, landmark learning appears to be determined not only by absolute proximity to the goal but also by relative proximity.

The much higher accuracy on single landmark test trials in this experiment compared with Experiment 3 may reflect the difference in the arrangement of stimuli. Recent unpublished research in my laboratory (Spetch, 1994) has indicated that human participants are much more likely than pigeons to show a relational use of landmarks (e.g., to learn that a goal is in the middle of a set of landmarks as opposed to learning the distance and direction from individual landmarks). Strong control by individual landmarks may be less likely to emerge when the position of the goal with respect to the landmarks lends itself to a simple relational rule. In Experiment 3, learning a between-the-landmarks rule may have interfered with control by the individual landmarks.

General Discussion

The occurrence of overshadowing of landmark control may not seem surprising given that overshadowing is a fundamental and pervasive phenomenon in associative learning. It was first documented in classical conditioning by Pavlov (1927) and has since been demonstrated a number of times in a variety of classical and instrumental conditioning situations (e.g., Couvillon & Bitterman, 1980; James & Wagner, 1980; Jarbe, Svensson, & Laaksonen, 1983; Kamin, 1969; Mackintosh, 1976; Mackintosh & Reese, 1979; Miles & Jenkins, 1973). However, the occurrence of overshadowing within these traditional forms of learning does not guarantee its occurrence in other forms of learning. For example, Galef and Durlach (1993) failed to find evidence of the conditioning phenomena of overshadowing, blocking, or latent inhibition in social enhancement of food preferences. Moreover, in some situations, such as flavor-aversion learning, potentiation rather than overshadowing effects sometimes occur (e.g., Bouton, Dunlap, & Swartzentruber, 1987; Rusiniak, Palmerino, & Garcia, 1982). Thus, the occurrence of overshadowing in spatial landmark learning was not a foregone conclusion.

My results demonstrate that, for both pigeons and humans, the extent to which a given stimulus gains control as a landmark for spatial search depends on the presence of other potential landmarks during training. Specifically, the control acquired by a landmark was overshadowed when it

occurred together with a landmark that was closer to the goal. These results extend those reported previously by Chamizo et al. (1985) and March et al. (1992) in suggesting that overshadowing does occur in spatial learning. In the Chamizo et al. and March et al. studies, this overshadowing was between two different types of stimuli—intramaze and extramaze cues—in a radial maze task with rats. In the current research, the overshadowing occurred between stimuli of the same type, graphic landmarks, in a touch-screen task with pigeons and humans. There are numerous differences between the radial maze task, which involves travel through three-dimensional space and multiple goal sites, and the two-dimensional touch-screen task used here. The fact that an overshadowing effect has been found in both situations lends further support to the suggestion (Spetch et al., 1992) that some of the processes governing spatial search and landmark use may have considerable generality.

My research demonstrates the occurrence of an overshadowing effect in landmark learning and shows that this effect depended, at least in part, on the spatial relationship of the overshadowing stimulus to the goal rather than on the inherent properties of the overshadowing stimulus. However, my research leaves open the question of what mechanism is responsible for overshadowing. In associative learning, overshadowing effects have been alternatively explained as arising from processes of selective attention (e.g., Mackintosh, 1971), competition for a limited amount of associative strength (Rescorla & Wagner, 1972), or stimulus generalization from the training compound to the element presented during the test (Pearce, 1987). A challenge for the future will be to design tests to distinguish between alternative mechanisms of overshadowing in the present type of task.

One question raised by my work is whether the landmark learning studied in the touch-screen task is really similar to that displayed by organisms in "real-space" tasks. Obviously, there are many differences between searching for a location on a small two-dimensional screen and moving through an environment in search of a goal. Nevertheless, results to date have suggested that landmark control in the touch-screen task is surprisingly similar to that seen in analogous search tasks in three-dimensional space. For example, Spetch et al. (1992) studied landmark control when the goal was located in a fixed place near either the top edge or the left edge of the monitor screen and a single graphic landmark was located near the goal. Their results were consistent with those obtained by Cheng and Sherry (1992) in a laboratory open-field task in which birds searched for food that was hidden near one edge of an experimental tray and a single-object landmark was located near the goal. In both environments, pigeons showed more control by the nearby landmark when it was shifted in directions parallel to the nearest edge than when it was shifted in directions perpendicular to the nearest edge. When the landmark was shifted diagonally, searching shifted more in the direction parallel to the edge than in the direction perpendicular to the edge. Spetch and Wilkie's (1994) finding that search was controlled primarily by the nearest landmark in the touch-screen task was also consistent with Cheng's (1989) finding

that pigeons show greater control by a near than a far landmark in the open-field task. Spetch and Wilkie also found that search in the touch-screen task was jointly controlled by a local landmark and global screen-location cues. This is consistent with findings that search in an open-field task is controlled by more than one source of spatial information (Cheng, 1988). Unpublished data from my laboratory have revealed additional similarities in the way in which landmarks control behavior in both touch-screen and real-space environments. Although external validation of the touch-screen task is a continuing process, the evidence to date suggests that it is a good model for studying pigeons' landmark-based spatial search.

It is important to note, however, that the touch-screen task is not intended as a model for all types of landmark learning but instead is intended only as a model of how local landmarks are used to locate a hidden goal in a search space that is defined and oriented by other cues. In nature, visual landmarks can serve a variety of roles that are not captured in the present task. For example, distal visual landmarks may be used to orient oneself and establish a cognitive map of a large-scale environment. Landmarks used in a cognitive mapping sense may serve to define regions in space and their relationship to one another for use in navigating among locations in the environment. In navigational situations, visual stimuli may also be used as recognition landmarks (e.g., to determine whether one is in familiar or unfamiliar territory). Finally, visual landmarks may serve as beacons for use in navigating toward a general goal region. It is possible that the processes governing the use of landmarks that serve these roles may be different from the processes governing the use of proximal landmarks that serve primarily to pinpoint a goal in a small, familiar, and directionally stable search space. Thus, the landmark-based search studied here involves a restricted kind of landmark learning.

It is interesting to note that the effects of spatial variables in this type of landmark learning seem to parallel those of temporal variables in Pavlovian conditioning. First, the finding that landmark learning is affected by the absolute spatial proximity of the landmark to the goal (Cheng, 1989; Spetch & Wilkie, 1994) seems to parallel the effect of absolute temporal proximity of the Conditioned Stimulus (CS) to the unconditioned stimulus (US) in Pavlovian conditioning. There is also some evidence that close spatial proximity of the CS and the US can facilitate Pavlovian conditioning (e.g., Rescorla & Cunningham, 1979). Second, the overshadowing effect in the current research showed that close spatial proximity alone is not sufficient to ensure that a stimulus will be used as a landmark, just as temporal contiguity of the CS and US is not sufficient to ensure that a CS will come to elicit a conditioned response. In particular, our finding in Experiments 3 and 4 of overshadowing by a spatially more-proximal stimulus is analogous to the overshadowing by a temporally more-proximal stimulus that was demonstrated in taste-aversion learning (Kaye, Gambini, & Mackintosh, 1988). Interestingly, Cheng (1992) also noted parallels between the psychophysics of time and space perception.

Despite these parallels, landmark learning seems distinct

from Pavlovian conditioning. It seems unlikely, for example, that the landmarks in my task were functioning purely as CSs. Although these landmarks signaled the availability of reinforcement, they did not provide particularly informative temporal signals for reinforcement, at least within the context of the session. The time between trials was short (5 s) relative to the trial duration (which often lasted more than 5 s). In addition, with the exception of landmark FAR in Experiments 1 and 2, each landmark was available on only half of the trials, and by the end of training only 50% of the trials were reinforced. Moreover, the elicited response of pigeons to localized signals for food is typically approaching and pecking at the signals. To obtain food in my task, the pigeons had to peck a certain distance and direction away from each landmark. The similar pattern of results obtained with human participants, who were instructed to find the goal and received points as reinforcers, further strains an interpretation in terms of purely elicited behavior.

Procedurally, the landmark-based search task is much closer to traditional instrumental learning, in that reinforcement is contingent on the occurrence of a particular response. In this task, the response that subjects must make to obtain reinforcement is locating and responding to the goal. Thus, a landmark may be viewed as a kind of discriminative stimulus. However, the landmark not only indicates when a response will be reinforced or which response will be reinforced, but it also specifies exactly where that response must occur in relation to itself. Whereas stimulus control in instrumental learning is typically described as learning to respond in the presence of stimuli, my landmark-learning task entails learning to respond at a specific location relative to stimuli. This requirement adds a uniquely spatial component to the stimulus control that develops. Nevertheless, it seems reasonable to consider a landmark as a specific kind of discriminative stimulus—one that controls the location of responding. From this view, one might expect to find that many of the principles of learning derived from studies using more traditional discriminative stimuli will show parallels in spatial landmark learning. As noted earlier, the selective control by only some landmarks in a display parallels the selective-attention effects that have been observed in traditional instrumental procedures.

Regardless of whether spatial landmark learning is viewed as being related to or distinct from the traditional forms of associative learning, it seems clear that further exploration of the extent to which the basic principles of learning apply to spatial tasks is warranted. Learning where to respond can be just as important in a variety of situations as learning when to respond. The decades of research on "what makes some stimuli effective" (Domjan, 1993, p. 86) in classical and instrumental learning would be nicely complemented by further attention to this question in the spatial domain.

References

- Bouton, M. E., Dunlap, C. M., & Swartzentruber, D. (1987). Potentiation of taste by another taste during compound aversion learning. *Animal Learning and Behavior*, 15, 433–438.

- Cartwright, B. A., & Collett, T. S. (1982). How honeybees use landmarks to guide their return to a food source. *Nature*, *295*, 560–564.
- Cartwright, B. A., & Collett, T. S. (1983). Landmark learning in bees. *Journal of Comparative Physiology. A: Sensory, Neural, and Behavioral Physiology*, *151*, 521–543.
- Chamizo, V. D., Sterio, D., & Mackintosh, N. J. (1985). Blocking and overshadowing between intra-maze and extra-maze cues: A test of the independence of locale and guidance learning. *Quarterly Journal of Experimental Psychology*, *37B*, 235–253.
- Cheng, K. (1988). Some psychophysics of the pigeon's use of landmarks. *Journal of Comparative Physiology. A: Sensory, Neural, and Behavioral Physiology*, *162*, 815–826.
- Cheng, K. (1989). The vector sum model of pigeon landmark use. *Journal of Experimental Psychology: Animal Behavior Processes*, *15*, 366–375.
- Cheng, K. (1990). More psychophysics of the pigeon's use of landmarks. *Journal of Comparative Physiology. A: Sensory, Neural, and Behavioral Physiology*, *166*, 857–863.
- Cheng, K. (1992). Three psychophysical principles in the processing of spatial and temporal information. In W. K. Honig & J. G. Fetterman (Eds.), *Cognitive aspects of stimulus control* (pp. 69–88). Hillsdale, NJ: Erlbaum.
- Cheng, K. (1994). The determination of direction in landmark-based spatial search in pigeons: A further test of the vector sum model. *Animal Learning and Behavior*, *22*, 291–301.
- Cheng, K., Collett, T. S., Pickard, A., & Wehner, R. (1987). The use of visual landmarks by honeybees: Bees weight landmarks according to their distance from the goal. *Journal of Comparative Physiology. A: Sensory, Neural, and Behavioral Physiology*, *161*, 469–475.
- Cheng, K., & Sherry, D. (1992). Landmark-based spatial memory in birds (*Parus atricapillus* and *Columba livia*): The use of edges and distances to represent spatial positions. *Journal of Comparative Psychology*, *106*, 331–341.
- Cheng, K., & Spetch, M. L. (in press). Stimulus control in the use of landmarks by pigeons in a touch-screen task. *Journal of the Experimental Analysis of Behavior*.
- Collett, T. S., Cartwright, B. A., & Smith, B. A. (1986). Landmark learning and visuo-spatial memories in gerbils. *Journal of Comparative Physiology. A: Sensory, Neural, and Behavioral Physiology*, *158*, 835–851.
- Couvillon, P. A., & Bitterman, M. E. (1980). Some phenomena of associative learning in honeybees. *Journal of Comparative and Physiological Psychology*, *94*, 878–885.
- Couvillon, P. A., Leiato, T. G., & Bitterman, M. E. (1991). Learning by honeybees (*Apis mellifera*) on arrival at and departure from a feeding place. *Journal of Comparative Psychology*, *105*, 177–184.
- Domjan, M. (1993). *The principles of learning and behavior* (3rd ed.). Belmont, CA: Wadsworth.
- Dyer, F. C., & Gould, J. L. (1983). Honey bee navigation. *American Scientist*, *71*, 587–597.
- Etienne, A., Teroni, E., Hurni, C., & Portenier, V. (1990). The effect of a single light cue on homing behaviour of the golden hamster. *Animal Behaviour*, *39*, 17–41.
- Galef, B. G., & Durlach, P. J. (1993). Absence of blocking, overshadowing, and latent inhibition in social enhancement of food preferences. *Animal Learning and Behavior*, *21*, 214–220.
- Gallistel, C. R. (1990). *The organization of learning*. Cambridge, MA: MIT Press.
- James, J. H., & Wagner, A. R. (1980). One-trial overshadowing: Evidence of distributed processing. *Journal of Experimental Psychology: Animal Behavior Processes*, *6*, 188–205.
- Jarbe, T. U. C., Svensson, R., & Laaksonen, T. (1983). Conditioning of a discriminative drug stimulus: Overshadowing and blocking like procedures. *Scandinavian Journal of Psychology*, *24*, 325–330.
- Kamin, L. J. (1969). Selective association and conditioning. In N. J. Mackintosh & W. K. Honig (Eds.), *Fundamental issues in associative learning* (pp. 42–64). Halifax, Nova Scotia, Canada: Dalhousie University Press.
- Kaye, H., Gambini, B., & Mackintosh, N. J. (1988). A dissociation between one-trial overshadowing and the effect of a distractor on habituation. *Quarterly Journal of Experimental Psychology*, *40B*, 31–47.
- Mackintosh, N. J. (1971). An analysis of overshadowing and blocking. *Quarterly Journal of Experimental Psychology*, *23*, 118–125.
- Mackintosh, N. J. (1974) *The psychology of animal learning*. San Diego, CA: Academic Press.
- Mackintosh, N. J. (1976). Overshadowing and stimulus intensity. *Animal Learning and Behavior*, *4*, 186–192.
- Mackintosh, N. J., & Reese, B. (1979). One-trial overshadowing. *Quarterly Journal of Experimental Psychology*, *31*, 519–526.
- March, J., Chamizo, V. D., & Mackintosh, N. J. (1992). Reciprocal overshadowing between intra-maze and extra-maze cues. *Quarterly Journal of Experimental Psychology*, *45B*, 49–63.
- Mather, J. A. (1991). Navigation by spatial memory and use of visual landmarks in octopuses. *Journal of Comparative Physiology. A: Sensory, Neural, and Behavioral Physiology*, *168*, 491–497.
- Miles, C. G., & Jenkins, H. M. (1973). Overshadowing in operant conditioning as a function of discriminability. *Learning and Motivation*, *4*, 11–27.
- Pavlov, I. P. (1927). *Conditioned reflexes* (G. V. Anrep, Trans.). London: Oxford University Press.
- Pearce, J. M. (1987). A model for stimulus generalization in Pavlovian conditioning. *Psychological Review*, *94*, 61–73.
- Rescorla, R. A., & Cunningham, C. L. (1979). Spatial contiguity facilitates Pavlovian second-order conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, *5*, 152–161.
- Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. Black & W. F. Prokasy (Eds.), *Classical conditioning II* (pp. 64–99). New York: Appleton-Century-Crofts.
- Reynolds, G. S. (1961). Attention in the pigeon. *Journal of the Experimental Analysis of Behavior*, *4*, 203–208.
- Rusiniak, K. W., Palmerino, C. C., & Garcia, J. (1982). Potentiation of odor by taste in rats: Tests of some nonassociative factors. *Journal of Comparative and Physiological Psychology*, *96*, 775–780.
- Spetch, M. L. (1994, June). *Selective use of landmarks to find a goal: Touch-screen studies with pigeons and people*. Paper presented at the meeting of the Canadian Society of Brain, Behavior, and Cognitive Science, Vancouver, British Columbia, Canada.
- Spetch, M. L., Cheng, K., & Mondloch, M. V. (1992). Landmark use by pigeons in a touch-screen spatial search task. *Animal Learning and Behavior*, *20*, 281–292.
- Spetch, M. L., & Edwards, C. A. (1988). Pigeons', *Columba livia*, use of global and local cues for spatial memory. *Animal Behaviour*, *36*, 293–296.
- Spetch, M. L., & Mondloch, M. V. (1993). Control of pigeons' spatial search by graphic landmarks in a touch-screen task.

- Journal of Experimental Psychology: Animal Behavior Processes*, 19, 353–372.
- Spetch, M. L., & Wilkie, D. M. (1994). Pigeons' use of landmarks presented in digitized images. *Learning and Motivation*, 25, 245–275.
- Suzuki, S., Augerinos, G., & Black, A. (1980). Stimulus control of spatial behavior on the eight-arm maze in rats. *Learning and Motivation*, 11, 1–18.
- Tinbergen, N. (1972). *The animal in its world*. Cambridge, MA: Harvard University Press.
- Vander Wall, S. B. (1982). An experimental analysis of cache recovery in Clark's nutcracker. *Animal Behaviour*, 30, 84–94.
- Wehner, R., & Rüber, F. (1979). Visual spatial memory in desert ants, *Cataglyphis bicolor* (Hymenoptera: Formicidae). *Experientia*, 35, 1569–1571.

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