

## The spatial distribution of pigeons' target detection

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### Abstract

Pigeons were trained to detect briefly-presented targets that appeared on a flatscreen computer display. Pecks were detected by a touchscreen mounted on the display. Those that were directed at the targets produced grain reward whereas pecks at locations in which the target had not appeared did not produce reward. A "behavioral fixation" procedure was used to ensure that the pigeons were facing the display when the target was presented. In general, the probability of detecting a target was highest in the region surrounding the fixation point and decreased as the target appeared more peripherally, both horizontally and vertically. These results show that pigeons' ability to detect targets in a frontal plane is not uniform.

*Key words:* Vision; Target detection; Pigeon

### 1. Introduction

In many species the ability to visually detect targets (prey, conspecifics, predators and the like) is of fundamental importance. This may be especially true for many avian species for which vision is the primary sensory ability (see for example ref. 6). Amongst avian species, the common pigeon has been extensively studied in vision research (see for example refs. 1–3). In the present report we describe a behavioral procedure for measuring pigeons' ability to detect targets that appear in a perpendicular plane in front of the subjects. A "behavioral fixation" procedure (e.g. Martinova et al. [3<sup>a</sup>]) was used to ensure that subjects were in a fixed spatial location at the time of target presentation. We used VGA computer monitor and touchscreen technology to present stimuli and record responses. In brief, trials in a target detection task began with the presentation of a small red square in the center of the VGA monitor. A peck at this "fixation point" produced a target and distractor stimuli in various parts of the screen. Pigeons received grain reward for pecking at the target location. Percent correct detections as a function of target location was measured.

### 2. Materials and Method

#### 2.1. Subjects

The subjects were two King pigeons and one homing pigeon. The subjects lived in large plastic-coated wire mesh cages in a climate-controlled colony (20 °C) that had a light:dark period matched to natural sunrise:sunset times. Subjects had free access to vitamin (Nekton-K) fortified water, crushed oyster shells and granite grit. The subjects received sufficient mixed grain during experimental sessions and post-session feedings to maintain their body weight at approximately 95% of free-feeding weights.

All subjects had participated in previous experiments unrelated to the present and in different apparatus than that employed in the present experiment.

#### 2.2. Apparatus

One end of a 34 cm (W) by 29 cm (H) by 42 cm (L) wooden chamber contained an opening that abutted to a Zenith Model 1492 14-inch flatscreen VGA computer monitor (20.5 cm H, 27.5 cm W), the screen of which was covered with a 10.7 cm sheet of clear Plexiglas. The other end consisted of sliding door through which a subject was introduced to and removed from, the chamber. A Hewlett-Packard Model D1183A touchscreen was mounted over the monitor screen. Each side wall contained an opening

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providing access to a standard grain feeder hopper. An exhaust fan was mounted on the ceiling of the chamber.

The monitor was operated in VGAMED mode (640 by 350 pixels, 70 Hz refresh rate, 16 colors). The touchscreen, capable of decoding 3713 points (79 horizontal by 47 vertical), provided "touch" information (push, move, or release) at 60 Hz. The array of light emitting diodes on the touchscreen were 1.6 cm from the monitor screen.

A networked 286 computer controlled stimulus presentation on the VGA monitor, monitored touchscreen activity, operated the grain feeders when appropriate and recorded data on a floppy disk and to a remote 486 server computer. The computer was programmed using Borland Turbo C++ and the Hewlett-Packard ATIOS.TC and BTIOS.TC Libraries. Data were analyzed using Systat for Windows [5].

### 2.3. Stimuli

Table 1 shows the VGA *x-y* coordinates of the 17 square stimuli (VGA color 4-red or VGA color 1-blue) used in the experiment. The squares were centered on two 45° diagonals that formed an X-shape on the monitor. One diagonal ran from top-left to bottom-right. The other ran from bottom-left to top-right. The square at the intersection of the two diagonals is called the center location. Using the center location as a reference, there were four locations to the up and right, four to the down and right, four to the up and left and four to the down and left.

The screen produced a luminance of 22.5 cd/m<sup>2</sup> as measured by a Minolta LS-110 Luminance Meter.

Table 1

The *x-y* coordination of the 17 square VGA monitor locations used as stimuli in the experiment. The top-left of the monitor had the coordinates 0,0, the bottom-right, 640,350.

Number	Top left		Bottom-right	
	<i>x</i>	<i>y</i>	<i>x</i>	<i>y</i>
1 (Center)	290	156	350	194
2	350	118	410	156
3	410	80	470	118
4	470	42	530	80
5	530	4	590	42
6	230	118	290	156
7	170	80	230	118
8	110	42	170	80
9	50	4	110	42
10	230	194	290	232
11	170	232	230	270
12	110	270	170	308
13	50	308	110	346
14	350	194	410	232
15	410	232	470	270
16	470	270	530	308
17	530	308	590	346

### 2.4. Preliminary procedures

Because all subjects had prior experimental experience, little preliminary training was required. All subjects simply received a few sessions in which they were autoshaped to peck at a red square in the center of the VGA monitor (area 1 in Table 1). An 8-s presentation of the red square was followed by 4-s of access to mixed grain in either the left or right feeder (randomly determined). Pecks at the red square turned the stimulus off and immediately operated the feeder.

Once the subjects were reliably pecking at the red square, food was made response contingent. Each of 34 daily trials began with the presentation of the center red square. A peck to this stimulus immediately caused the square to change from red to blue for 1 s, after which the square was again red. The next peck turned the red square off and operated one of the feeders. (The occasional pecks made to the blue square had no programmed consequences.) Once subjects were reliably pecking the red→blue→red stimulus, this stimulus was presented on the remaining 16 locations. On each trial, the location was randomly selected.

### 2.5. Experiment proper

In the experiment proper, subjects received 34 trials in each session, with sessions occurring around 10.00, generally 5 days per week. During initial sessions, adjustments were made to various trial parameters. The following is a description of the final trial parameters. Trials were separated by a 10-s intertrial interval, spent in darkness. All trials began with the presentation of the center red square. The square remained on the screen until it was pecked. When the subject pecked the center red square, the square was turned off for 0.5 s. Then all 17 red squares were presented. After the passage of 0.5 s, one red square (randomly selected from the list of 17 locations) was immediately replaced with a blue square for 1 s, after which time it reverted to red. A single peck to the square that had switched from red to blue to red turned off the display and immediately produced a 4-s grain reward. A peck to any other square simply turned off the display.

In each session, a record was kept of the frequency of each of the 17 trial types and the frequency of correct choices on each trial type. These data were then used to calculate a percent correct score for each location. If subjects did not learn the task, or did not see certain locations on the monitor and consequently chose randomly, a score of 5.9% correct would be expected.

Data were collected in 76 sessions after the final trial parameters were set. The results reported below are based on all of these sessions. These data were collected between

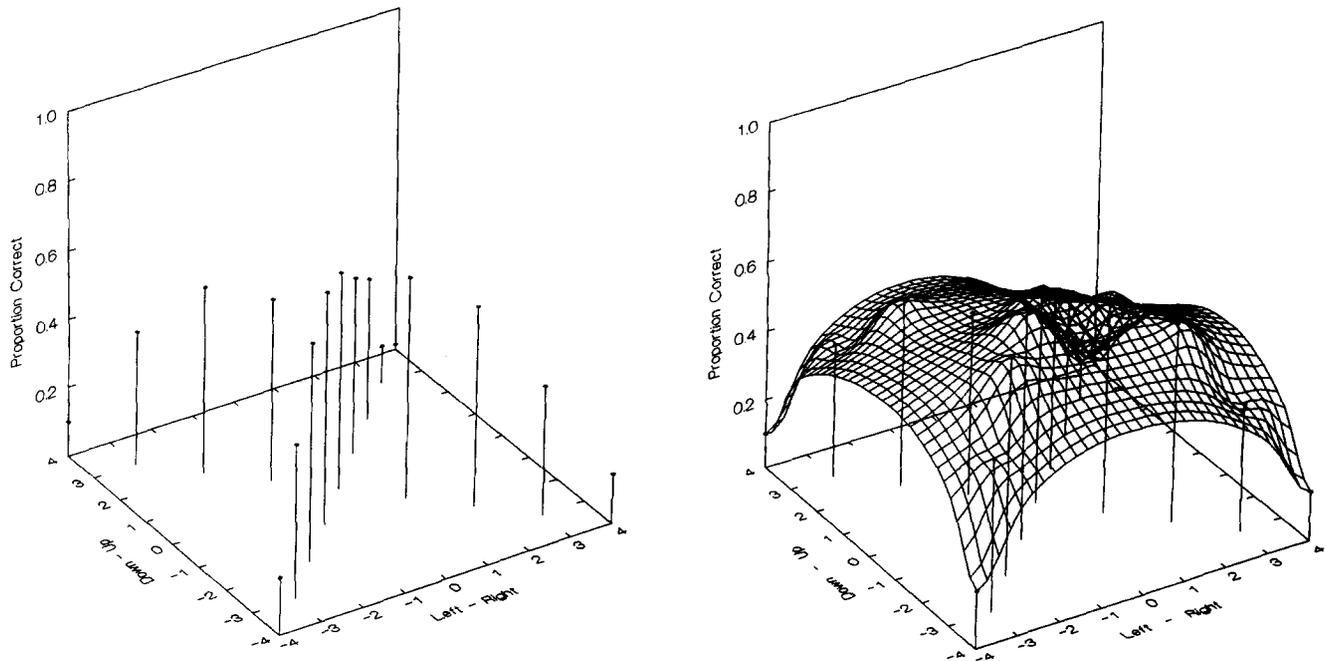


Fig. 1. Percent correct detections as a function of target location. These data are averages over all sessions for all subjects.

December 10, 1992 and April 16, 1993. During this period sunrise:sunset times (and the colony light:dark cycle) varied from 07.57/16.14 05.19/19.06 PST.

### 3. Results and discussion

Fig. 1 shows percent correct detections at each of the positions, for each of the 17 target locations on the monitor, averaged over all of the sessions and all of the subjects. In this plot the center of the screen is given the coordinates 0,0. The top-right corner target location has coordinates of 4,4 and so forth. The left-hand panel shows percent correct at each of the 17 locations. In the right-hand panel a surface has been fit to the data using the inverse option in Systat for Windows.

If subjects were incapable of detecting targets and simply responded randomly, percent correct scores at each location would be 5.9%. As can be seen in Fig. 1, subjects choose correctly at much higher levels than this chance level, clearly indicating that they had learned the target detection task and that they were capable of detecting targets. However, it is also clear from this figure that target detection was not uniform over the monitor. Subjects tended to detect more targets presented in the center of the screen. Correct detections decreased as targets occurred more laterally and above and below the "fixation point". Target detection decreased to approximately the same extent in both of these dimensions.

The latter observation is seen clearly in Fig. 2. This

figure collapses the data in Fig. 1 into vertical and horizontal dimensions. The data at 0 on the  $x$ -axis are for the center of the display. The data at  $-1$  are the two target locations immediately to the left of center on the horizontal dimension (one above center and one below center) and the two target locations immediately below the center on the vertical dimension (one to the left and one to the right of center). Similarly, the data at  $+1$  are for the two target locations immediately to the right of center and immediately above center.

The observations noted above were verified by statistical analyses. First, a one-sample  $t$ -test verified that performance over the 17 locations depicted in Fig. 1 (mean

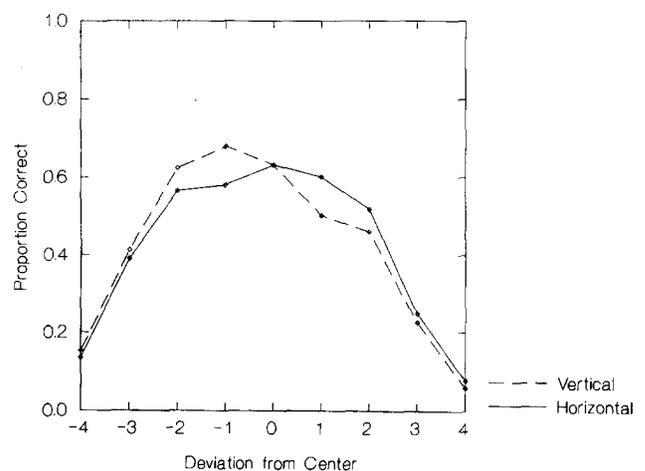


Fig. 2. Replot of Fig. 1 into vertical and horizontal dimensions. See text for details.

40.5%) was significantly above chance levels of 5.9%,  $t_{16} = 6.52$ ,  $P < 0.0001$ . As well, differences in performance at the different locations were statistically significant— $F_{16,32} = 7.55$ ,  $P < 0.0001$  in a Subjects by Location repeated measures ANOVA.

In summary, the present results show that pigeons' ability to detect briefly presented targets in a frontal plane is not homogeneous over that plane. Rather, the ability to detect targets decreases in an orderly manner as targets become more peripheral to a central "fixation point". This result is interesting given that the pigeon has laterally placed eyes that presumably allows a panoramic field of view. There is some overlap of the two monocular visual fields, resulting in a frontal binocular field. The area of high target detection does not seem to correspond to this binocular field, which is an ovoid area about  $114^\circ$  in vertical extent and about  $37^\circ$  in horizontal extent (e.g. ref. 4). If pigeons only detected targets that they saw binocularly, the areas of high detection presented in Fig. 1 should have an ovoid rather than a circular shape.

Because target detection decreased in a systematic manner around the "behavioral fixation point" this procedural feature appears to have achieved its main goal. A potential complicating factor using this procedure, however, is that pigeons sometimes peck with their heads tilted to the right or left. During casual observations of our subjects we sometimes saw this, but not on all trials and not in a consistent direction. At present we cannot suggest what role tilted pecking may play in target detection.

It is interesting to compare the present results with those reported by Yamashita [7]. In that study, pigeons were trained to discriminate between S+ and S- stimuli that were presented horizontally on either side of a central fixation point. The stimuli that were presented adjacent to the fixation point were viewed binocularly whereas those presented more laterally were viewed monocularly. The fact that the pigeons discriminated S+ and S- equally well at all locations led Yamashita to conclude that the pigeons' frontal visual field is perceptually homogeneous and that the binocular/monocular distinction does not affect visual discriminations. Our data seem consistent with the latter point but clearly are at odds with the notion that the pigeons' perceptual field is homogeneous. A probable explanation of this discrepancy is the fact that Yamashita presented stimuli along a horizontal line that was 2.5 cm

in length. In contrast we presented targets over a horizontal dimension of 27.5 cm. If we only consider targets near to the center of the display we too see evidence of perceptual homogeneity. However, this homogeneity disappears when targets are presented more distally.

In the Introduction we argued that target detection is an important perceptual ability that alerts animals to prey, predators and other important biological events. One must be cautious in applying the present findings to animals in natural settings. Although our results may suggest that pigeons would not see a target item that appeared peripherally, or at least is less likely to do so, it must be kept in mind that we used a fixation procedure. Animals in natural environments are not always so constrained. The fact that animals can move and can engage in scanning behavior, probably decreases the chances that a target will be missed because it appeared in a "perceptual hole".

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