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ATTENTION AND "VISUAL FIELD DEPENDENCY" IN THE PIGEON[1]

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Three pigeons were trained in an upright conditioning chamber to peck a key transilluminated by a vertical line. This training was followed by a line orientation generalization test. During the test, the chamber was tilted laterally 22.5 degrees from upright. The chamber floor remained horizontal with respect to gravity. Under these conditions, the subjects responded more often in the presence of a visually vertical (parallel to chamber walls) line orientation than in the presence of a gravitationally vertical line orientation. Subsequent reinforcement of pecking in the presence of a line that was always gravitationally vertical but not always visually vertical temporarily abolished this "visual field dependency" and resulted in generalization gradients with peak responding in the presence of the gravitationally vertical line orientation. The results are discussed in terms of selective attention to the gravitational and visual components of line orientation.

"Field dependency" in human subjects is measured by a variety of tests including the rod-and-frame test. During this test, subjects in a dark room face a luminous frame that encompasses a movable luminous rod. With the frame tilted at various angles from gravitational vertical, the subjects are required to position the rod in a gravitationally vertical position. Some subjects are free from systematic error in positioning the rod and are said to be "field independent"; other subjects make consistent errors—typically, positioning the rod in a direction toward the tilted frame—and are said to be "field dependent" (*cf.* Witkin, Lewis, Hertzman, Mackover, Meissner, and Wapner, 1954). Thomas and Lyons (1968) reported an apparently similar phenomenon in pigeons. In their experiment pigeons were initially trained, in a conditioning chamber that was in its normal upright position, to peck a key transilluminated by a white line. The line was both gravitationally and visually vertical (*i.e.*, parallel to the chamber walls). During a subsequent line orientation generalization test, the chamber was tilted laterally a number of degrees from gravitational vertical. The floor of the chamber was tilted an equal number of degrees in the opposite direction so that it remained horizontal with respect to gravity. Line orientations visually vertical (parallel to wall) and to the right and left of visual vertical were presented during the test. The resulting generalization gradients were symmetrical and had peak values at the visual vertical line orientation. Had the birds not been affected by the tilt of the chamber walls the gradients should have been asymmetrical, with more responding during line orientations closer to gravitational vertical. Since this was not observed, Thomas and Lyons concluded that the pigeon is "visually field dependent".

One way of analyzing the "visual field dependency" effect in the pigeon is in terms of *selective attention* or *selective stimulus control* (*cf.*, Skinner, 1953; Terrace, 1966). These terms denote the fact that a response is controlled by one stimulus or stimulus dimension and is not controlled by another stimulus or stimulus dimension. A controlling relation between a stimulus dimension and a response is measured by stimulus variation. If stimulus variation, such as that arranged during a Guttman and Kalish (1956) -type generalization test, produces systematic variation in response probability, that stimulus or stimulus dimension is said to control the response. Alternatively, if such variation does not systematically influence response probabilities, it is said that the stimu-

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lus or stimulus dimension does not control the response or that the organism is not attending to that stimulus or stimulus dimension. Selective stimulus control or attention has been observed in numerous experiments, two of which are now classic. Lashley (1938), after training rats to jump to a card containing a form, found that the rats' jumping was selectively controlled by the size of the form or by only a part of the form. Reynolds (1961) reinforced pecking by pigeons in the presence of a white triangle on a red background but not in the presence of a white circle on a green background and then presented the color and form elements separately during an extinction test period. He reported that one pigeon responded only during presentation of the red background while another pigeon responded only during presentation of the triangle.

The vertical line that served as the training stimulus in Thomas and Lyons' experiment can be viewed as a compound stimulus consisting of redundant visual and gravitational (postural) elements. A vertical line is visually parallel to the chamber walls and has a defined gravitational relationship to the organism. From this point of view, their pigeons were selectively controlled by the visual rather than by the gravitational aspect of line orientation in the same manner that one of Reynold's pigeons was controlled by the form but not the color element of the stimulus. The fact that all of Thomas and Lyons' pigeons attended to the visual rather than the gravitational aspect of line orientation suggests that the visual element was more "distinctive" or higher in these subjects' "attending hierarchy" (*cf.*, Baron, 1965) than the gravitational element. While the question of why organisms are sometimes more likely to attend to one particular aspect of a stimulus, like the question of why organisms sometimes attend to several aspects of a stimulus and at other times only one, is still unanswered, the phenomenon has been observed in several experiments. Warren (1953), for example, reported that monkeys attended to color more often than to form or size. Other research has shown that an organism's "attending hierarchy" can be modified and that control by a non-distinctive aspect can be established. For example, Newman (1963) found that pigeons, when trained to peck a key transilluminated by a white vertical line on a green background, and not to peck a key transilluminated by either red or a white line on red, did not attend to the line orientation aspect of the stimulus. Control by the "non-distinctive" line orientation aspect was established, however, when pecking during the presence of the line on the green background was reinforced and pecking during the green background by itself was non-reinforced.

The purpose of the present research was to provide empirical verification of this selective attention analysis of "visual field dependency" in the pigeon. The experiment consisted of several phases. The first phase (Training Condition 1 and Generalization Test 1) was concerned with establishing that the subjects were under the control of line orientation. The second phase (Training Condition 2 and Generalization Test 2) consisted of a systematic replication of Thomas and Lyons' (1968) experiment. The major part of the experiment (Training Conditions 3 to 12 and Generalization Tests 3 to 12) followed and was concerned with attempting to establish control by the gravitational rather than the visual aspect of line orientation. Two different procedures were used in attempting to establish attention to the gravitational aspect of line orientation. In both procedures, reinforcement for pecking was consistently associated with a gravitationally vertical but not a visually vertical line orientation. One prediction that follows from the selective attention analysis of the "visual field dependency" effect is that it should be possible to establish control by the gravitational aspect of line orientation.

METHOD

Subjects

Three, adult White King pigeons were maintained at approximately 80% of normal free-feeding body weight throughout the experiment by grain obtained during experimental sessions and by post-session supplemental feeding as required. Water and grit were always available in the home cage. One pigeon (P-3) was experimentally naive; the others (P-1 and P-2) had previously served in a variety of experiments.

Apparatus

The experimental space was a BRS-Foringer Model PS-004 three-key pigeon chamber. In the present experiment only the center key was operative. Operation of this key required a peck having a force of about 0.20 N. Mounted directly behind this clear plastic key was an Industrial Electronic Engineers' stimulus display cell that projected a 2.54 by 0.32 cm (1 by 0.125 in.) white line at various orientations on a blue surround. A solenoid-operated grain feeder was located directly below the center key. Two, #313 lamps mounted behind a transparent plastic strip located above the keys served as houselight. During reinforcement periods, which consisted of 5-sec access to mixed grain, the display cell was turned off. Simultaneously, a #313 lamp illuminated the grain in the feeder tray. The houselight was illuminated at all times during experimental sessions. Lateral tilting of the chamber and chamber floor was accomplished by placing wooden ramps under the chamber and floor. The chamber air blower and white noise attenuated extraneous sounds. Solid state logic circuits automatically scheduled experimental events and recorded data.

Procedure

The procedure for each subject is summarized, in schematic form, in Figure 1. Each subject was exposed to a series of training conditions. The subjects were exposed to each training condition for a minimum of seven sessions. Each training condition was followed by a generalization test in which lines of different orientation were presented.

Training Condition 1. The subjects were first exposed, with the chamber in its normal, non-tilted orientation, to two orientations of a white line. One line orientation was gravitationally and visually vertical (*i.e.,* parallel to the chamber walls). Key pecking in the presence of this orientation was reinforced according to a variable-interval 1-min (VI 1-min) schedule. The other line orientation was horizontal. Pecking in the presence of this orientation was not reinforced. The two line orientations were presented successively and alternated with each other in a regular manner throughout the session. Each was presented for a period of 3 min and was followed by a 5-sec period in which the display unit was turned off.

Training Condition 2. This condition was identical to the first condition.

Training Condition 3. One-third of the sessions of this condition were identical to those of Conditions 1 and 2. During the other sessions, the experimental chamber was tilted laterally either 22.5 degrees clockwise (one-third of sessions) or 22.5 degrees counterclockwise (one-third of sessions). During the sessions in which the chamber was tilted, the floor of the chamber was tilted 22.5 degrees in a direction opposite to the tilt of the chamber so that the chamber floor was always gravitationally horizontal. During each block of three sessions, each chamber orientation (vertical, 22.5 degrees clockwise, and 22.5 degrees counterclockwise) occurred once. The order of occurrence of the different chamber orientations within each block of three sessions was random. During all sessions in this condition, line orientations that were gravitationally vertical (during which pecking was reinforced on a VI 1-min schedule) and gravitationally horizontal (during which pecking was nonreinforced) alternated with each other. In one third of the sessions, the line orientation associated with reinforcement was also visually vertical (parallel to walls). During the remaining sessions, this line was either 22.5 degrees clockwise or 22.5 degrees counterclockwise from visual vertical.

Training Condition 4. Indentical to Conditions 1 and 2.

Training Condition 5. Identical to Conditions 1, 2, and 4.

Training Condition 6. Identical to Condition 3.

Training Condition 7. Identical to Conditions 1, 2, 4, and 5.

Training Condition 8. Identical to Conditions 1, 2, 4, 5, and 7.

Training Condition 9. Identical to Condition 6.

Training Condition 10. During one half of the sessions in this condition, the chamber was tilted either 22.5 degrees clockwise (one quarter of the sessions) or 22.5 degrees counterclockwise (one quarter of the sessions). During sessions in which the chamber was tilted, the floor was tilted an equal number of degrees in the opposite direction so that it remained horizontal. During the sessions in which the chamber was upright, key pecking in the presence of a line that was both gravitationally and visually vertical was reinforced on a VI 1-min schedule. This line orientation alternated with either a line which was 22.5 degrees clockwise (one quarter of the sessions) or

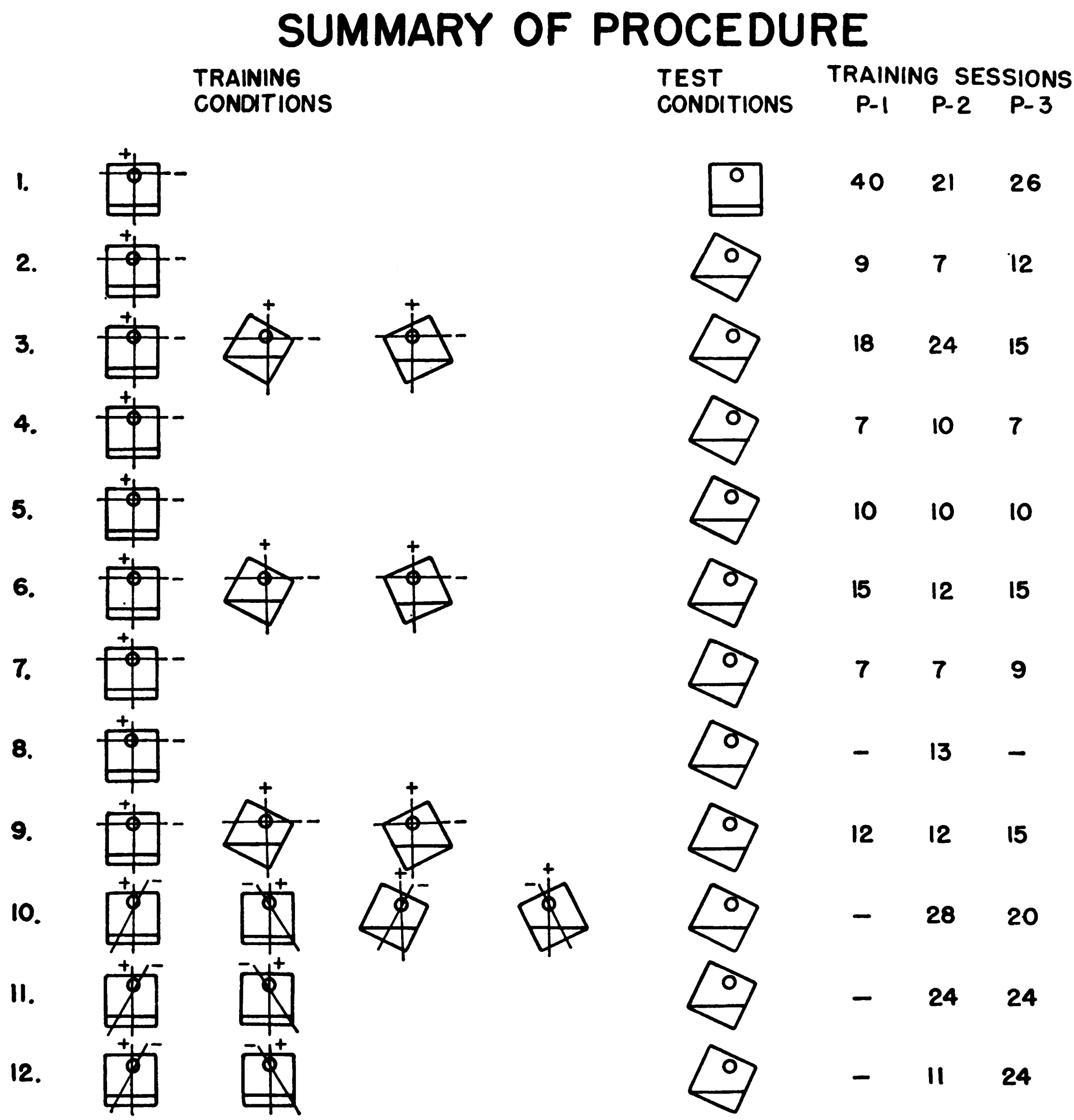

Fig. 1. Schematic summary of training and testing procedures for each subject. Chamber orientation (vertical, 22.5 degrees clockwise, and 22.5 degrees counterclockwise), floor orientation (always horizontal), line tilt associated with reinforcement (+), and line tilt associated with nonreinforcement (−) are shown for each training condition. Also shown are the chamber and floor orientation used during the generalization tests that followed the various training conditions and the number of sessions the subjects were exposed to the various training conditions.

22.5 degrees counterclockwise (one quarter of the sessions) from visual and gravitational vertical. Pecking in the presence of these two orientations was not reinforced. During the sessions in which the chamber was tilted, a gravitationally vertical line alternated with a visually vertical line. Pecking in the presence of the gravitationally vertical but not the visually vertical line was reinforced. During each block of four sessions, each of these four different conditions occurred once. The order of occurrence of the different conditions within each block was random.

Training Condition 11. During this condition, the chamber was always upright. Pecking in the presence of a line that was both visually and gravitationally vertical was reinforced on a VI 1.0-min schedule. During one-half of the sessions the line tilt associated with nonreinforcement was 22.5 degrees clockwise from visual and gravitational vertical. During the other sessions, the line associated with extinction was 22.5 degrees counterclockwise from visual and gravitational vertical. During each block of two sessions, each of these orientations occurred. The order of occurrence was random within each block.

Training Condition 12. Identical to Condition 11.

Generalization tests. Each of the above training conditions was followed by a generalization test. During the tests, no reinforcers were delivered. Except during the generalization test that followed Training Condition 1, the chamber was always tilted 22.5 degrees clockwise, and the floor 22.5 degrees counterclockwise so that it remained horizontal with respect to gravity. During the first generalization test, neither chamber nor floor were tilted. During each test, lines of different orientations (±67.5, ±45, ±22.5, and 0 degrees from visual vertical for Subjects P-1 and P-3; ±45, ±22.5, and 0 degrees from visual vertical for Subject P-2) were presented. Each orientation was presented for 1 min and was followed by a 5-sec period in which the display cell was turned off. Each line tilt was presented five (seven for Subject P-2) times during a test. The order in which the different line tilts were presented during a test was randomized with the restriction that all orientations had to occur before an orientation was repeated.

Generalization test sessions lasted approximately 35 min. Training sessions typically lasted 1 hr. Sessions were conducted daily at approximately the same time.

Table 1

Mean response rate (responses per minute) during line orientations associated with reinforcement availability (S+) and non-availability (S−) during the various training conditions. Averages for Training Conditions 1 to 9 are based on the last three sessions; averages for Training Conditions 10 to 12 are based on the last four sessions. The different training conditions are summarized in Figure 1.

Training Condition	*Subject* P-1 S+	P-1 S−	P-2 S+	P-2 S−	P-3 S+	P-3 S−
1	42.9	0.1	60.5	0.5	50.8	0.6
2	30.0	0.2	52.1	0.9	59.1	1.4
3	39.6	0.1	72.1	0.1	59.9	0.1
4	42.5	0.1	60.6	0.1	65.9	0.3
5	30.0	0.1	46.0	0.1	69.2	0.1
6	41.9	0.1	74.8	0.1	75.0	0.6
7	43.4	0.1	51.1	0.0	69.6	0.2
8	–	–	51.7	0.0	–	–
9	32.4	0.0	57.6	0.0	74.2	0.6
10	–	–	76.8	14.2	64.4	11.5
11	–	–	74.3	2.7	85.7	11.2
12	–	–	81.8	0.8	71.9	1.1

RESULTS

Table 1 shows the mean response rate during the line orientations associated with reinforcement availability and reinforcement non-availability during the various training conditions. Each subject responded differentially in the presence of these line orientations during all training conditions.

Of main interest in the experiment was the location of the peak of the gradient observed during the generalization tests that followed the different training conditions. These gradients, as well as a schema of the training and testing conditions, are shown in Figures 2, 3, and 4. Since the location of the gradient peak, rather than the actual number of responses that occurred in the presence of a particular line orientation, was the datum of primary interest in the experiment, the gradients are presented as relative gradients. The relative gradients were calculated by dividing the number of responses made during a particular line orientation by the number of responses made during the line orientation during which responding was most frequent. Thus, the line orientation during which responding was most frequent has a relative responding value of 1.0.

Generalization test 1. The purpose of this test was simply to ascertain if the subjects were under the control of line orientation. As can be seen in the upper left-hand panels of Figure 2, 3, and 4, all subjects were under the control of line orientation. Maximal responding during the test occurred during the line orientation associated with reinforcement during the previous training condition. Less responding occurred during the other orientations.

Generalization test 2. This test was an attempt to replicate Thomas and Lyons' (1968) observation that pigeons are "visually field dependent". Their observation was confirmed. All subjects responded maximally during the test in the presence of a line orientation that

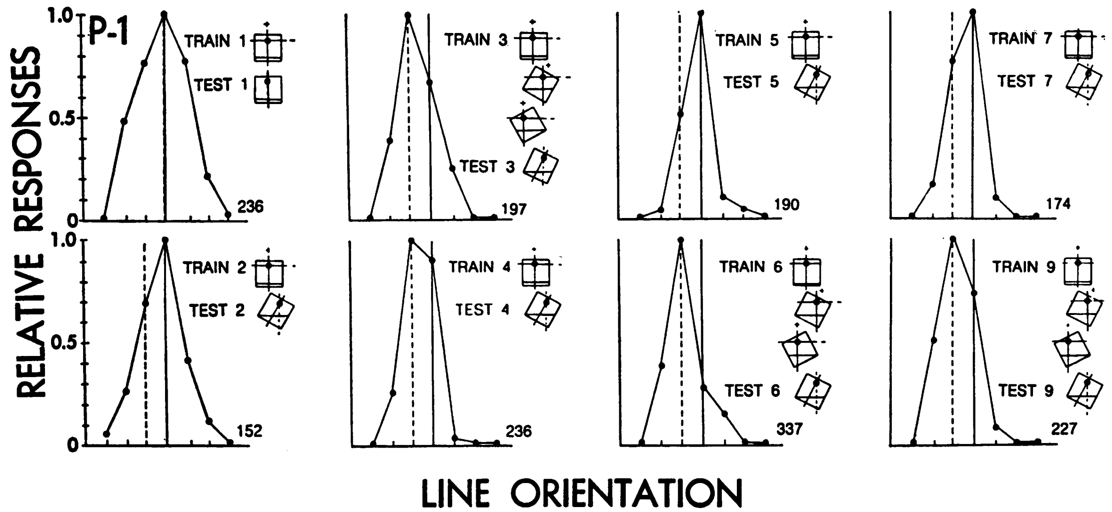

Fig. 2. Relative responding during the various generalization tests for Subject P-1. Also shown are schema of the training conditions that preceded the tests and the test conditions. Gravitationally vertical line tilt is indicated by a dash line; visually vertical line tilt is indicated by a solid line. The number in the lower right-hand corner of the panels is the number of responses emitted during the line tilt having a relative frequency of 1.0. The actual number of responses emitted during any particular line tilt can be calculated from this number.

was visually vertical (22.5 degrees clockwise from gravitational vertical).

Generalization Test 3. This test followed exposure to the training condition in which the natural association between gravitational vertical and visual vertical was destroyed. Maximal responding during this test occurred in the presence of the gravitationally vertical line, rather than in the presence of the visually vertical line. Thus, reinforcing pecking during a line orientation that was always gravitationally vertical but not always visually vertical was effective in bringing the subjects under the control of the gravitational aspect of line tilt.

Generalization test 4. This test was to ascertain if control by the gravitational aspect of line orientation was "durable". After generalization test 3, pecking in the presence of a line that was both gravitationally and visually vertical was again reinforced for between seven and 10 sessions. The subjects then received generalization test 4. All subjects were still under the control of the gravitational aspect of line orientation at this stage: peak responding occurred during the gravitationally vertical line orientation.

Generalization test 5. This test was given after an additional 10 sessions of reinforcement for pecking in the presence of a visually and gravitationally vertical line. After this period, the subjects were once again under the control of the visual aspect of line orientation. All sub-

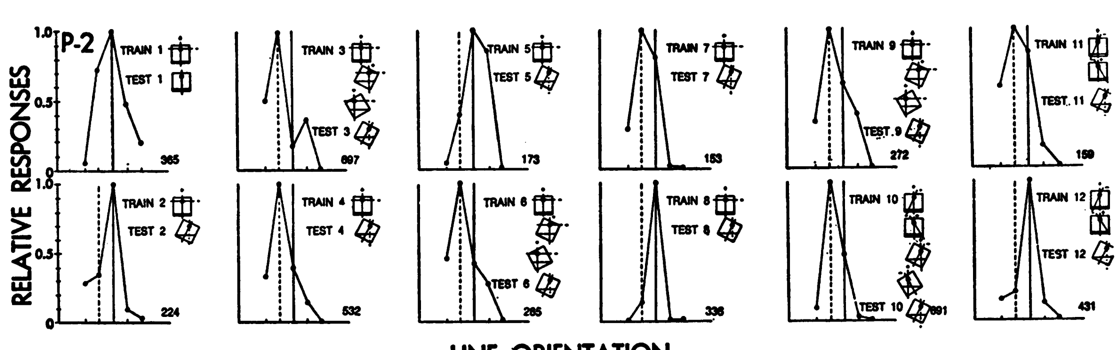

Fig. 3. Relative responding during the various generalization tests for Subject P-2.

jects showed maximal responding during the generalization test in the presence of the visually vertical line orientation.

Generalization test 6. This test followed additional sessions in which pecking during a gravitationally vertical line was always reinforced while pecking during a visually vertical line was not always reinforced. Again, the effect of this training was to produce peak responding during the gravitationally vertical line orientation in the generalization test.

Generalization test 7. After pecking in the presence of a line that was both gravitationally and visually vertical was reinforced for seven or nine sessions, two subjects (P-1 and P-3) responded most often during the ensuing generalization test to the visually vertical line orientation. The other subject (P-2) again peaked at the gravitationally vertical line orientation.

Generalization test 8. Following an additional 13 sessions in which pecking during a line both gravitationally and visually vertical was reinforced, Subject P-2 responded most often during this generalization test in the presence of the visually vertical line orientation.

Generalization test 9. All subjects again showed peak responding during the gravitational vertical line in this test, which followed additional sessions in which responding during a gravitationally but not always a visually vertical line orientation was reinforced.

Generalization test 10. During one half of the sessions of Training Condition 10, responding in the presence of a gravitationally vertical line orientation was differentially reinforced. During these sessions, pecking during the gravitationally vertical line orientation was reinforced while pecking in the presence of the visually vertical line tilt was extinguished. During the remaining sessions, pecking during a line both gravitationally and visually vertical was reinforced while pecking at a line either 22.5 degrees clockwise or 22.5 degrees counterclockwise from gravitational and visual vertical was extinguished. These training conditions resulted in control by the gravitational aspect of line orientation. Both subjects that were exposed to Training Condition 10 (P-2 and P-3) showed maximal responding during the generalization test in the presence of the gravitational vertical line orientation.

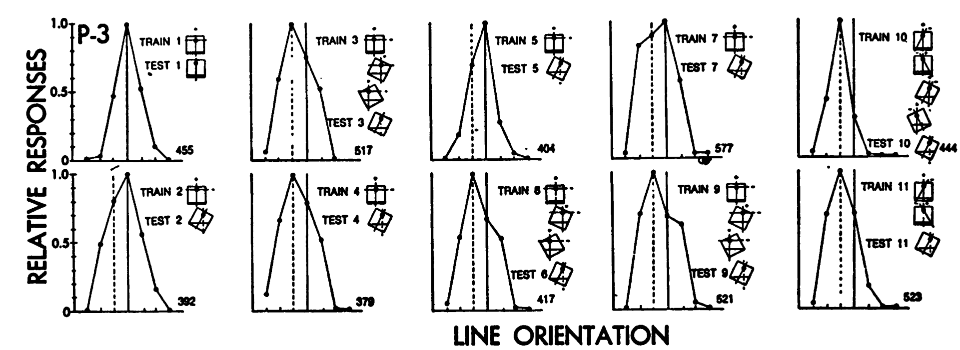

Fig. 4. Relative responding during the various generalization tests for Subject P-3.

Generalization test 11. Subjects P-2 and P-3 continued to show maximal responding during the gravitationally vertical line orientation when tested after 24 sessions of exposure to reinforcement for pecking in the presence of a line that was both gravitationally and visually vertical.

Generalization test 12. Both Subjects P-2 and P-3 responded most often during this test in the presence of a line that was visually vertical.

Other results. One other aspect of the generalization test data deserves mention. There was no systematic decrease in the absolute number of responses during the successive generalization tests. Since the tests were performed during extinction periods one might have expected that the absolute number of responses would decrease as a function of the number of tests. However, this was not the case for any of the subjects. Which factor was responsible for the failure of the subjects to discriminate test from training sessions in the present experiment is not clear.

DISCUSSION

The results of the first part of the present experiment replicate Thomas and Lyons' (1968) finding that the pigeon is "visually field dependent". After being trained in an upright chamber to peck in the presence of a line that was both visually and gravitationally vertical, the birds received a line orientation generalization test with the chamber tilted 22.5 degrees counterclockwise. During this test, the subjects responded maximally during a line orientation that was parallel to the chamber walls (visually vertical rather than to a line that was gravitationally vertical).

The results of subsequent parts of the experiment showed that this "visual field dependency" effect was reversible. Exposure to two different training procedures in which reinforcement was consistently associated with a gravitationally but not always a visually vertical line resulted in maximal responding during generalization tests in the presence of a line that was gravitationally vertical. These results provide empirical support for a selective attention interpretation of the "visual field dependency" effect. In these terms, the effect is an instance in which only one aspect of a complex stimulus (the parallel relationship between the chamber walls and the line orientation displayed on the key) controls responding. Since all the pigeons tested in the present experiment and in Thomas and Lyons' experiment attended to this aspect of line orientation, it would appear that this relationship is a prepotent one for the pigeon. This phenomenon appears to be an instance of the operation of an "attending hierarchy", such as that reported by Newman (1963) for lines and color in the pigeon. The outcome of the present experiment can be viewed as an instance in which control by an initially prepotent or "distinctive" element of a complex stimulus was abolished and replaced by control by an initially "non-distinctive" element. Consistent association of reinforcement with the initially non-distinctive element but not with the initially distinctive element appears to be a sufficient condition for the transfer of control to the non-distinctive element.

It is not entirely clear whether it should be concluded that the present procedures resulted in "field-independence" in the strict sense of the term. Peak responding during the gravitationally vertical line orientation would be expected if the birds were attending either to the relationship between postural stimuli and line orientation or to the perpendicular visual relationship between the gravitationally vertical line and the chamber floor. The latter possibility seems unlikely, however, since this relationship is apparent only to an organism that is some distance from the line stimulus—a condition that does not occur when a pigeon is key pecking. Also, it has been shown (Lyons and Thomas, 1968) that pigeons do attend to the relationship between postural stimuli and line orientation when the possibility of attending to the relationship between the chamber walls and line orientation is absent (*i.e.,* in a dark chamber).

One of the most interesting results of the present experiment was the temporary nature of the attention to the gravitational aspect of line orientation. One might have expected that once the birds were attending to the gravitational aspect of line orientation that they would continue to do so. It is commonly believed that stimulus control, once established, persists until there has been a departure from the contingencies that maintain it. However, this was clearly not the case in the present experiment: all of the subjects "reverted" to attending to the visual aspect of line orientation despite the fact that reinforcement continued to be differentially available in the presence of a gravitationally vertical line orientation.

The finding that attention to the gravitational aspect of line orientation was only temporary is not incompatible with some recent notions in the operant conditioning literature. Ray (1969) suggested that the stimulus control or attention relationship can be viewed as having many of the properties of an operant response. One of the major ideas in her treatment is that a controlling stimulus-response relationship can be characterized by its frequency or probability of occurrence. Another major idea is that several stimulus control relationships may exist concurrently at a given time. Thus, shifts in stimulus control or attention would be similar to the phenomenon of one response "displacing" another: the displaced stimulus control relationship has not ceased to exist but merely has been replaced by another relationship. If one views the gravitational relationship as being a less prepotent relationship than the visual relationship, then the shift in attention from gravitational to visual aspects of line orientation could be considered to be an instance in which a prepotent stimulus control relationship displaces a stimulus control relationship that is lower in the pigeon's attending hierarchy. A similar phenomenon in which a "prepotent", phylogenetically controlled behavior displaced a reinforced behavior was reported by Breland and Breland (1961). The drift in attention in the present experiment may represent an analogous displacement process in stimulus control relationships.

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