

Visual and spatial probability learning in pigeons and goldfish*

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Pigeons and goldfish received 600 guidance trials on a 70:30 probability discrimination, with either color or position irrelevant. The fish ended up choosing the majority stimulus on approximately 70% of trials, the pigeons on about 90% of trials. Most Ss in all conditions showed significant biases to one or the other value of the irrelevant dimension, and when they received a further 750 trials on a 50:50 reinforcement schedule, they either maintained these biases or developed new ones. Neither pigeons nor goldfish, therefore, showed random probability matching.

Experiments on probability learning, in which a correction or guidance procedure is used to ensure complete exposure to the reinforcement schedule, have been thought to reveal important differences in the behavior of different animal groups. Bitterman (1965, 1969, 1971), for example, has argued that nonmammalian vertebrates (e.g., pigeons and goldfish) often show random probability matching (at any rate on visual problems), while mammals (e.g., rats) do not. To qualify as displaying random matching, animals must first distribute their responses between the two stimuli in approximate proportion to the probability of reinforcement on each, and secondly must do so without displaying any nonrandom response tendencies. Choices might be nonrandom in either of two ways: animals might show systematic reward-following or a systematic negative recency effect with respect to the relevant stimuli, or they might have systematic response biases to irrelevant stimuli.

There is no real dispute about the behavior of rats in probability learning experiments: they typically exceed a matching level of performance, and they also show systematic response tendencies—occasionally reward-following on the relevant stimuli (Bitterman, 1971; Mackintosh, 1970), and always showing systematic response tendencies to irrelevant stimuli (e.g., selecting the last rewarded position in a visual problem, or maintaining relatively strong position biases: cf. Mackintosh, 1970). In the case of birds and fish, however, matters are less certain. Fish, it appears, tend to match the probability of reinforcement quite closely—although perhaps slightly exceeding matching on spatial

problems (Behrend & Bitterman, 1961, 1966); but, although Bitterman has claimed that pigeons do not usually exceed matching on visual problems, the weight of the evidence suggests that they and other birds, such as chicks, usually do (Shimp, 1966; see also Mackintosh, 1969, for a discussion of some of Bitterman's data). Furthermore, although there is evidence that neither chicks (Mackintosh, 1969) nor goldfish (Behrend & Bitterman, 1966) show systematic response tendencies such as reward-following to the relevant stimuli, there is virtually no evidence on how nonmammalian vertebrates distribute their responses to irrelevant stimuli. Mackintosh (1969) has reported data showing significant irrelevant response tendencies in chicks, but there are no data on pigeons or fish. The primary purpose of the present experiment was to

provide such data for pigeons and goldfish trained either on visual probability discriminations (with spatial cues irrelevant) or on spatial problems (with visual cues irrelevant).

METHOD

The Ss were 16 White Carneaux pigeons approximately 6 months old, maintained at 80% of their ad lib weights, and 16 5-in.-long goldfish. The apparatus used for the pigeons was a standard two-key chamber enclosed in a sound-attenuating shell. Red, green, or white lights could be projected onto the response keys, and there was a central magazine opening and a houselight. The apparatus for the goldfish consisted of a black Plexiglas screen which could be inserted to cover one end wall of a 2-gal tank which was housed in a sound-attenuating chamber. The screen contained two 1-in.-diam holes, 2 in. apart, behind which were paddles and onto which red, green, or white lights could be projected. There was a magazine opening, covered by a sliding shutter midway between the two paddles, through which Tetramin tube food could be delivered in controlled quantities from a motor-operated syringe. A houselight was situated over the middle of the tank. (Further details of this type of apparatus are provided in Mackintosh & Cauty, 1971).

The training procedure was identical for pigeons and goldfish. Ss were first trained to eat from the magazine and were then reinforced for responding to whichever key was illuminated with a white light. Once responding was reliably established, Ss received 50

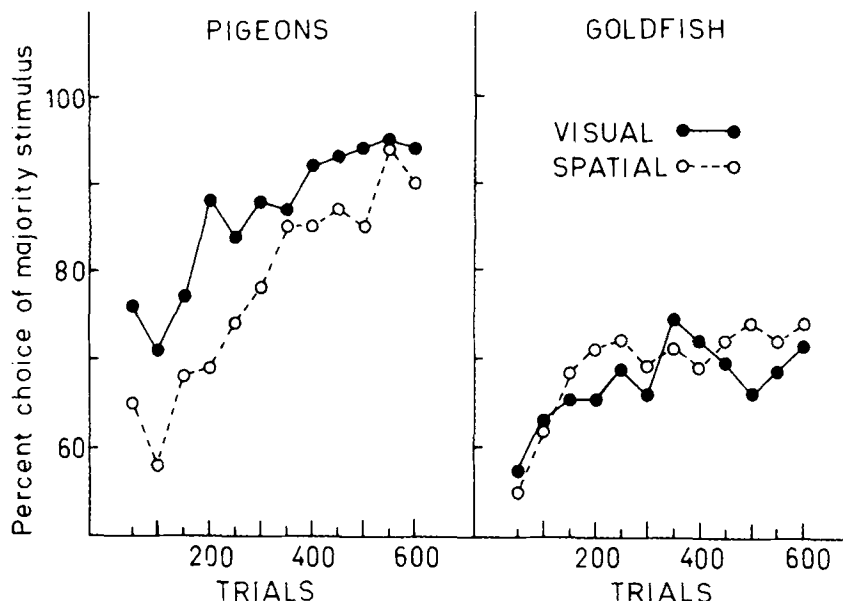


Fig. 1. Group mean learning curves for 70:30 problem.

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trials on a 100:0 schedule of reinforcement and then 50 trials a day for 12 days on a 70:30 schedule of reinforcement. Eight pigeons and eight goldfish were trained on a red-green discrimination with position irrelevant (four with red, four with green as the majority stimulus), while eight were trained on a spatial problem with the visual stimuli irrelevant (four with left, four with right as the majority stimulus). The position of the majority color (or the color of the majority position) was determined by Gellermann sequences, and the reinforcement schedule was random with the restrictions that seven majority stimulus rewards occur in each block of 10 trials and that not more than two minority stimulus rewards occur in succession.

A trial started with the turning off of the houselight and illumination of the response keys; a response on either key turned both off and, if scheduled for reinforcement, led to the operation of the food magazine (3 sec for the pigeons; 2-sec delivery of food with the shutter raised for 5 sec for the goldfish). A nonreinforced response was followed by a 6-sec blackout, after which only the reinforced key was illuminated, response to which was rewarded in the usual way (this defines a guidance training procedure). Each trial was followed by a 25-sec intertrial interval with the houselight on. Only initial choices were recorded.

After 12 days of 70:30 training, four pigeons which had received visual training and eight goldfish (four visual and four spatial) received a further 15 days of training on a 50:50 reinforcement schedule.

RESULTS

The results of 70:30 training are shown in Fig. 1. Over the final 250 trials, the pigeons averaged 93.37% (SD = 6.02) choice of the majority stimulus in the visual problem, and 88.40% (SD = 13.62) in the spatial problem. The goldfish averaged 69.50% (SD = 5.72) choice of the majority stimulus in the visual problem, and 72.10% (SD = 6.56) in the spatial problem. The results for the goldfish conform rather closely to those previously reported by Behrend & Bitterman (1966)—close approximations to matching, with a very slight suggestion of better than matching performance on a spatial problem. The pigeons, however, clearly exceeded a matching level on both the visual and the spatial problems. The significance of group deviations from matching over the final 250 trials was assessed by *t* tests for paired means: the pigeons selected the majority stimulus on significantly more than 70% of trials in both visual and spatial problems ($t = 10.36$ and

Table 1
Analysis of Systematic Responses to Irrelevant Stimuli

	70:30 Training: Trials 351-600		50:50 Training: Trials 501-750	
	Visual Problem: Percentage of Errors Occurring to Preferred Side	Spatial Problem: Percentage of Errors Occurring to Preferred Color	Percentage of Responses Made to Preferred Side	Percentage of Responses Made to Preferred Color
Pigeons	79.2 (N = 4)	78.0 (N = 5)	69.0 (N = 4)	71.5 (N = 4)
Goldfish	67.6 (N = 8)	80.1 (N = 8)	58.2 (N = 8)	60.9 (N = 8)

3.56, $p < .01$); in the fish, neither difference approached significance ($t = 0.23$ and 0.84). An analysis of variance performed on these scores revealed a significant difference between pigeons and goldfish ($F = 40.3$, $df = 1/28$, $p < .001$) and no other significant effects.

Examination of trial-by-trial performance over the final 250 trials revealed no marked signs either of reward-following or of a negative recency effect with respect to the relevant stimuli. However, the majority of Ss showed marked biases with respect to irrelevant stimuli, making many more errors on trials when the minority stimulus took on one value of the irrelevant dimension than when it took on the other value. The percentage of errors over the final 250 trials made to each S's preferred value of the irrelevant dimension is shown in Table 1 (four pigeons learning the visual problem and three learning the spatial problem made errors on fewer than 5% of these trials; their scores are excluded from this analysis). The scores of all four groups showed highly significant deviations from a chance distribution of errors: chi-square tests yielded group effects that were all significant at better than the .001 level, and within all but one group the majority of Ss showed individual deviations from chance at better than the .05 level: this was true for three of four pigeons in the visual group, four of five pigeons in the spatial group, four of eight fish in the visual group, and seven of eight fish in the spatial group.

After completion of 70:30 training, some Ss were trained on a 50:50 reinforcement schedule. Here there is no distinction between correct responses and errors, but the question of interest was whether random probability matching, i.e., equal choice of all four stimuli (left, right, red, and green) would occur. Performance over the final 250 trials is shown in Table 1. Both pigeons and goldfish showed group deviations from chance that were significant at better than the .001 level for both visual and spatial choices. All four pigeons showed

individually significant ($p < .05$) deviations from 50% choice of one or the other visual stimulus, and three of the four also showed unequal choice of the spatial stimuli. Six of the eight goldfish showed individually significant ($p < .05$) deviations from chance choice of the visual stimuli, and four of the eight deviated from chance in their choice of the spatial stimuli: no S showed random choice of both visual and spatial stimuli. Not all of these biases were in accordance with those developed during 70:30 training: for example, two of the four pigeons reversed their visual preference during the course of 50:50 training.

DISCUSSION

The results of the present experiments are rapidly summarized. In terms of asymptotic choice of the majority stimulus, pigeons were significantly better at both visual and spatial probability learning than goldfish; while goldfish showed a close approximation to matching the probability of reinforcement, pigeons performed more closely to maximizing. Secondly, neither pigeons nor goldfish showed "random probability matching," if that term is understood to imply the complete absence of systematic response tendencies to irrelevant stimuli: both classes of animal (although pigeons to a greater extent than goldfish) made the majority of their errors to a particular irrelevant stimulus, and these biases either persisted or appeared *de novo* during subsequent 50:50 training.

The theoretical implications are twofold. First, there are no grounds for drawing a sharp qualitative distinction between the behavior of mammals and that of nonmammalian vertebrates in probability learning experiments. Rats, it is true, usually reach a higher asymptote than do either pigeons or goldfish (although hardly higher than the asymptote attained by pigeons in the present study); but this may reasonably be described as a quantitative difference in efficiency, since the only other basis for drawing a qualitative distinction (that rats show systematic response

tendencies while pigeons and goldfish do not) is invalidated by the present results. Secondly, these results, with their demonstration of significant response tendencies to irrelevant stimuli, are entirely consistent with the suggestion that a major cause of errors in probability learning is that animals fail to maintain consistent attention to the inconsistently reinforced relevant cue, and hence response to irrelevant cues (Mackintosh, 1969, 1970).

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