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RELATIVE IMPORTANCE OF TASTE AND VISION IN REDUCING BIRD DAMAGE TO CROPS WITH METHIOCARB, A CHEMICAL REPELLENT

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ABSTRACT

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The relative importance of taste and vision for methiocarb-induced food aversions was studied in captive house finches (*Carpodacus mexicanus*). Seed handling behavior and patterns of consumption of safflower seeds treated with methiocarb indicated that taste was not involved. Rather, the data suggest that, in the absence of visual cues to palatability, the finches responded to physiological effects following methiocarb ingestion. In an experiment to assess the effect of an added visual signal, pairs of finches given methiocarb-treated hulled oats with red tape on their food bowl showed more aversion to the treated food than did pairs without tape. These and other findings suggest that methods to reduce bird damage to crops with chemical repellents should emphasize visual cues rather than taste.

INTRODUCTION

Aversive conditioning using chemical repellents to cut crop losses to birds is not new (see Hermann and Kolbe, 1971), and methiocarb [3,5 dimethyl-4-(methylthio)-phenol methylcarbamate], has been evaluated often in recent years. An emetic, methiocarb also inhibits cholinesterase activity (Schlagbauer and Schlagbauer, 1972). Birds usually begin to vomit 10—15 min after eating methiocarb-treated seeds, and often then lose motor coordination. They recover within an hour and soon learn to avoid the treated food (J.G. Rogers, 1978, personal observations).

Methiocarb has been applied to various crops (Crase and De Haven, 1976) and tested in the laboratory (Schafer et al., 1975; Thompson et al., 1981), but few have studied the relative importance of taste and visual cues. Quelea (*Quelea quelea*) that were offered both dyed and flavored millet responded more to taste than color (Schumake et al., 1977), but these results were confounded by unequal palatabilities among the foods

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presented. Rogers (1974, 1978) attributed the responses of captive red-winged blackbirds (*Agelaius phoeniceus*) to taste aversion learning, but his birds took an average of 2.7 h to become conditioned (Rogers, 1974, table 1), a contradiction of the 'almost immediate' (Rogers, 1974, p. 419) response expected if taste was the basis for their behavior. Visual cues were not tested. Mason and Reidinger (1983a, b) have repeatedly shown color cues to be sufficient for methiocarb-induced food aversions by red-winged blackbirds, but they did not test taste cues.

PRELIMINARY TRIALS

Preliminary feeding experiments suggested that house finches did not use taste to avoid methiocarb-treated seeds. In one trial, three pairs of finches were successively given safflower seeds treated with 0%, 0.1%, 0.2%, 0.05%, and 0% methiocarb, with untreated millet always available as an alternative food. All three pairs responded similarly (Fig. 1), consistent with Rogers' (1978) findings: they recognized the absence of the chemical and, unlike rats (Galef and Clark, 1971), were not reluctant to eat formerly treated food. The finches apparently distinguished among treatment levels and adjusted their feeding accordingly (Fig. 1).

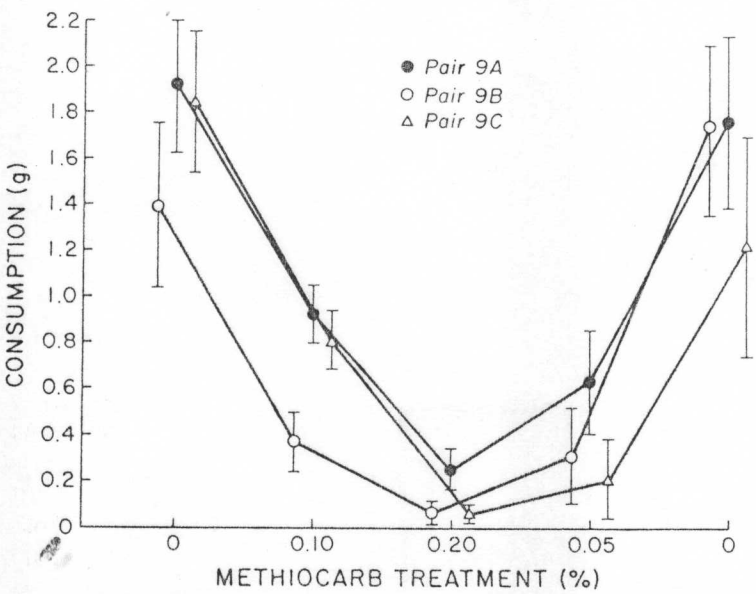

Fig. 1. Mean and standard deviation of safflower consumption by three pairs of house finches during successive 5-day series of 2-h trials involving seeds treated with different levels of methiocarb.

Such behavior is consistent with the idea that methiocarb is more distasteful at higher rates of application. Thus, the strength of the chemical's taste may indicate the treated food's degree of unpalatability (e.g., Dragoin,

1971). Alternatively, the birds may detect physiological changes associated with ingesting methiocarb (e.g., increased heart rate, Thompson et al., 1981), and respond by eating less of the treated item. This would occur more quickly with higher than lower treatment levels because more chemical per seed is ingested at higher levels.

Rogers (1974) proposed that responses based on taste should be more rapid than those effected by physiological changes. To test this, I observed several finches eating both treated and untreated safflower seeds. Even

TABLE I

Rejection rates by captive house finches of untreated safflower seeds and safflower seeds treated with methiocarb

Bird	Number of seeds handled		Percent rejected	
	Untreated	Treated	Untreated	Treated
A	462	428	73	76
B	131	37	61	46
C	30	9	60	44
D	94	7	44	43
E	27	28	41	36
F	26	19	38	16
G	104	15	27	40
H	14	22	14	23
	Median rejection rates:		42.5	41.5
	No significant difference		($P > 0.05$)	
	Mann-Whitney U test			

TABLE II

Rates of rejection by captive house finches of safflower seeds treated with methiocarb, during initial trials and trials 1—2 weeks subsequently

Bird	Encounters	Number of seeds		
		Eaten	Rejected	Percent rejected[a]
A	Initial	70	199	74.0
	Subsequent	33	126	79.2
B	Initial	14	8	36.4
	Subsequent	6	9	60.0
E	Initial	6	3	33.3
	Subsequent	12	7	37.1
F	Initial	5	2	28.6
	Subsequent	11	1	9.1
G	Initial	7	3	30.0
	Subsequent	10	2	16.7

[a]No significant differences ($P > 0.05$) in rejection rates. Chi-square and Fisher's exact tests.

when handling untreated seeds, each bird rejected a certain percentage before selecting one to eat (Table I), but did not differ in the rate of rejection of treated and untreated seeds. Also, the rejection rate of treated seeds was the same in later trials as during the initial exposure, 1—2 weeks earlier (Table II). These results go against the suggestions of Rogers (1974) and Rogers and Linehan (1977) for taste aversion learning. Instead, they suggest that the birds responded to the physiological effects of methiocarb ingestion.

In two experiments described below, I provide additional evidence that house finches do not readily avoid methiocarb-treated seeds in the absence of visual cues, and then describe the effect of an added visual signal on their ability to avoid treated seeds.

GENERAL METHODS

House finches trapped near Davis, CA in October 1980 were held in a large outdoor aviary for 2 months. Then, pairs (one male and one female) were selected at random and put into separate outdoor cages measuring 2.7 m × 1.8 m × 2.2 m. At the front of each cage, a wooden shelf 1.5 m from the floor held food items. Adjacent pairs could not see each other.

Trials involved free-choice tests between either safflower and millet, or hulled oats and canary seed. Consumption was measured by weighing contents of the seed bowls before and after each trial. I ignored spillage, as frequent observations showed that the birds wasted very little during the trials. Moisture gained or lost by seeds seldom exceeded 1%, so it too was ignored. Birds were fasted 30—60 min before each trial. When not being tested, finches were given ad libitum a seed mix not containing the test foods. They always had water and grit. Apples were provided two or three times weekly.

Seeds were treated by dissolving the appropriate amount of methiocarb (Mesurol®, 75% wettable powder) in 10—20 ml of acetone and mixing it thoroughly with the seeds. The mixture was dried 48 h before the seeds were used.

EXPERIMENT 1

If house finches use taste to distinguish untreated seeds from those treated with methiocarb, they should do so in the absence of visual cues. For instance, when offered two bowls of safflower seeds, one treated and one untreated, they should readily discriminate and eat mainly from the untreated bowl with little reduction in total safflower consumption.

Methods

I tested five pairs of finches in two 5-day series of 1-h feeding trials. In the first series, birds were offered two identical bowls each containing

5 g of untreated safflower seed. For each pair of birds, one bowl was arbitrarily designated 'treated'. In the second series, the treated bowl contained 5 g of safflower treated with 0.2% methiocarb. The position of the treated bowl was switched daily. Total safflower consumption was compared between series with a two-tailed Mann-Whitney *U* test (Sokal and Rohlf, 1969).

Results and discussion

Consumption was significantly ($P<0.02$) less during the test series than before (Table III). The mean reduction in consumption was substantial, 61%, indicating poor discrimination between treated and untreated seeds. The mean daily consumption of the five pairs tended to decline slightly during the trials, unlike the trend during the pre-treatment series (Fig. 2). Thus, these results provide no support for taste aversion learning by house finches.

TABLE III

Safflower consumption by five pairs of house finches exposed to one bowl of untreated seeds and one bowl of seeds treated with 0.2% methiocarb during 1-h trials on 5 consecutive days, compared with pre-treatment consumption from two bowls of untreated seeds

Pair	Treatment consumption (g)[a]	Percent reduction from pre-treatment	Proportion taken from the 'treated' bowl	
			Pre-treatment	Treatment
1	1.02 ± .22	47	0.47	0.31
2	0.80 ± .11	65	0.49	0.45
3	0.87 ± .25	62	0.46	0.34
4	0.80 ± .36	59	0.54	0.38
5	0.62 ± .24	74	0.46	0.50

[a]Mean ± one standard deviation.

However, for pairs 1, 3 and 4, the proportion taken from the treated bowl decreased considerably during the treatment (Table III), suggesting that these pairs were somewhat successful in identifying and avoiding the treated seed bowl. But, if their discrimination was by taste, it is difficult to understand why over 30% of the seeds eaten still came from the treated bowl. Rather, their activity was probably affected by physiological changes caused by the repellent. This process, slower than taste aversion learning (Rogers, 1974), may require consumption of several treated seeds before the effects are felt.

These results support the idea that house finches do not use nonvisual stimuli effectively in determining the palatability of food items. They reduced their consumption of safflower presumably because they could

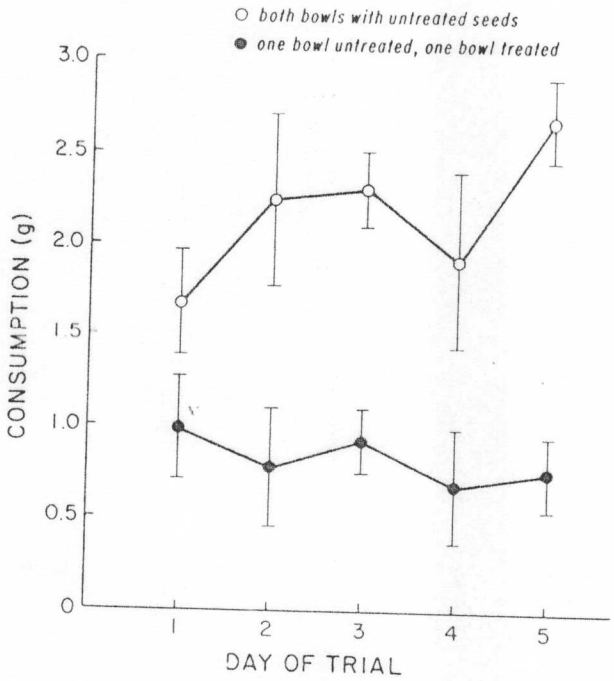

Fig. 2. Mean safflower consumption by five pairs of house finches during two 5-day series of 1-h trials. ○, first series; •, second series; vertical bars, standard deviation.

not reliably identify treated seeds without eating them. Thus, it is reasonable to investigate the importance of visual cues. Red-winged blackbirds can be conditioned with methiocarb to avoid food associated with colors (Mason and Reidinger, 1983a, b), and in Experiment 2, I tested this in house finches.

EXPERIMENT 2

Methods

Eight pairs of finches were randomly assigned to four groups of two pairs each. Two groups received 5 g of untreated canary seed and 5 g of untreated hulled oats, and the other two groups 5 g of untreated canary seed and 5 g of oats treated with 0.2% methiocarb. In addition, one treated group and one untreated group each had short strips of red electrical tape on the sides of their oat bowls. Thus, four subgroups were formed: no tape—no methiocarb, tape—no methiocarb, no tape—methiocarb, and tape—methiocarb. If they use red tape for differentiating palatable and unpalatable food, the tape—methiocarb pairs should eat less, and prefer oats less, than the no tape—methiocarb pairs. Also, the two methiocarb groups should eat less oats than the two groups without methiocarb.

One-hour trials were conducted on consecutive days. The birds were given one trial to accustom them to the procedure. The analysis used data from the next five trials in which a pair's total consumption (oats plus canary) was at least 0.2 g. Both absolute and proportional oat consumption were analyzed using a two-way analysis of variance (ANOVA). Proportional consumption was determined by dividing oat consumption by total consumption. These data were transformed to arcsine square root before analysis.

Results and discussion

As expected, pairs given methiocarb-treated oats ate less oats, absolutely and proportionally, than no methiocarb pairs (Table IV). The presence of red tape decreased consumption by both treated and untreated groups. The two-way ANOVA showed that both tape ($P<0.02$) and methiocarb ($P<0.001$) had significant effects on proportional consumption of oats. The same trend was apparent in the analysis of absolute oat consumption, but not significantly ($P>0.05$). There was no significant interaction ($P>0.25$) between tape and methiocarb.

TABLE IV

Absolute and proportional consumption of hulled oats by eight pairs of house finches exposed to treated (0.2% methiocarb) and untreated oats, with and without red tape attached to their bowls during 1-h trials on 5 consecutive days

	Absolute consumption (g)[a]		Proportional consumption[a]	
	No tape	Tape	No tape	Tape
		Untreated		
	0.64 ± .23	0.34 ± .09	0.85 ± .07	0.60 ± .24
	1.78 ± .39	0.53 ± .53	0.95 ± .04	0.74 ± .29
Mean	1.21	0.44	0.90	0.67
		Treated		
	0.08 ± .07	0.07 ± .07	0.22 ± .17	0.15 ± .12
	0.10 ± .08	0.02 ± .04	0.27 ± .24	0.08 ± .10
Mean	0.09	0.05	0.25	0.12

[a]Mean ± one standard deviation.

The tape–methiocarb treatment was the most effective in suppressing oat consumption, followed by methiocarb without tape. The lack of a significant interaction between tape and methiocarb indicates that the effect of the red tape was additive to that of the chemical. Apparently, the tape itself was somewhat aversive. The importance of cue additivity in food aversion learning has been shown previously (Best et al., 1976;

Martin and Lawrence, 1979), and my findings suggest that adding a visual cue did increase methiocarb's repellent effect. Mason and Reidinger (1983b) reached the same conclusion, but none of their birds was conditioned in the absence of color cues, so additive effects could not be evaluated.

My results are consistent with those of others (e.g., Best et al., 1976) in that simultaneous presentation of multiple cues provides a stronger stimulus than if each cue is presented separately. A predator may use several senses to evaluate potential prey (Eisner and Grant, 1981), and in a Batesian mimicry system, will tend to avoid those mimics whose signals most resemble those of the noxious model (Vane-Wright, 1981). The more offensive the model, the less perfect the mimic can be and still be protected (Brower et al., 1971), but the aversion will be strongest to the mimic having the most cues in common with the unpalatable model (Terhune, 1977; Martin and Lawrence, 1979; Mason and Reidinger, 1983a).

GENERAL DISCUSSION

It has been shown that some birds can discriminate among flavors (e.g., Duncan, 1960; Brindley, 1965), and house finches may be similar. However, there is no basis for assuming that this species forms taste aversions to food treated with methiocarb. If house finches do taste methiocarb, they do not associate the taste with induced illness. Domestic chicks behave similarly when conditioned with lithium chloride (Gillette et al., 1980).

The early experimental demonstrations of taste aversion learning in mammals (see Barker et al., 1977, for a comprehensive review) may have unduly influenced research on chemical repellents for avian crop pests. Rogers (1980) stated: "...we continue to emphasise this system [taste] in attempts to develop chemical means of dissuading birds from consuming agricultural crops". Perhaps this is the wrong emphasis, for as Wright (1980) observed: "...behaviour that gives every appearance of being taste-oriented may be controlled by other factors". The present study and Mason and Reidinger's (1983a, b) indicate that vision is the primary sense by which house finches and red-winged blackbirds discriminate methiocarb-treated food. Because there has been no unambiguous demonstration of taste aversion learning with methiocarb among the few bird species tested (Rogers and Linehan, 1977; Shumake et al., 1977; Rogers, 1978; Gustavson et al., 1982), it seems prudent that future efforts to enhance methiocarb's effectiveness should concentrate on the visual aspects of the birds' prey selection behavior (size, color, shape, location, etc.).

SUMMARY AND CONCLUSIONS

The above results do not support the idea that house finches form a taste aversion to seeds treated with methiocarb. They do suggest a less immediate response based on the bird's ability to evaluate the treated

food's relative toxicity by monitoring physiological changes caused by methiocarb. The sensory capabilities of birds which have been tested with repellents such as methiocarb are poorly understood, and even less is known about their perception of the chemical's physiological effects.

There is experimental evidence, however, to suggest that vision is important to aversive conditioning with methiocarb. Both in this study (Table IV) and elsewhere (Mason and Reidinger, 1983a, b), visual signals facilitated repellency. In the absence of conclusive evidence for taste aversion learning with methiocarb, future research efforts to enhance repellency should emphasize vision and the physiological effects of methiocarb-induced illness.

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REFERENCES

Barker, L.M., Best, M.R. and Domjan, M. (Editors), 1977. Learning Mechanisms in Food Selection. Baylor University Press, Waco, TX.

Best, P.J., Best, M.R. and Lindsey, G.P., 1976. The role of cue additivity in salience in taste aversion conditioning. Learn. Motiv., 7: 254—264.

Brindley, L.D., 1965. Taste discrimination in bobwhite and Japanese quail. Anim. Behav., 13: 507—512.

Brower, L.P., Alcock, J. and Brower, J.V.Z., 1971. Avian feeding behavior and the selective advantage of incipient mimicry. In: R.R. Creed (Editor), Ecological Genetics and Evolution. Blackwell, Oxford, pp. 261—274.

Crase, F.T. and De Haven, R.W., 1976. Methiocarb: its current status as a bird repellent. Proc. Vertebr. Pest Conf., 7: 46—50.

Dragoin, W.B., 1971. Conditioning and extinction of taste aversions with variations in intensity of the CS and UCS in two strains of rats. Psychon. Sci., 22: 303—305.

Duncan, C.J., 1960. Preference tests and the sense of taste in the feral pigeon. Anim. Behav., 8: 54—60.

Eisner, T. and Grant, R.P., 1981. Toxicity, odor aversion, and 'olfactory aposematism'. Science, 213: 476.

Galef, B.G., Jr. and Clark, M.M., 1971. Social factors in the poison avoidance and feeding behavior of wild and domesticated rat pups. J. Comp. Physiol. Psychol., 75: 341—357.

Gillette, K., Martin, G.M. and Bellingham, W.P., 1980. Differential use of food and water cues in the formation of conditioned aversions by domestic chicks (*Gallus gallus*). J. Exp. Psychol. Anim. Behav. Processes, 6: 99—111.

Gustavson, C.R., Holzer, G.A., Gustavson, J.C. and Vakoch, D.L., 1982. An evaluation of phenol methylcarbamates as taste aversion producing agents in caged blackbirds. Appl. Anim. Ethol., 8: 551—559.

Hermann, G. and Kolbe, W., 1971. Effect of seed coating with Mesurol® for protection of seed and sprouting maize against bird damage, with consideration to varietal tolerance and side effects. Pflanzenschutz-Nachr., 24: 279—320.

Martin, L.T. and Lawrence, C.D., 1979. The importance of odor and texture cues in food aversion learning. Behav. Neural Biol., 27: 503—515.

Mason, J.R. and Reidinger, R.F., Jr., 1983a. Generalization of and effects of pre-exposure on color avoidance learning by red-winged blackbirds (*Agelaius phoeniceus*). Auk, 100: 461—468.

Mason, J.R. and Reidinger, R.F., Jr., 1983b. Importance of color for methiocarb-induced food aversions in red-winged blackbirds. J. Wildl. Manage., 47: 383—393.

Rogers, J.G., Jr., 1974. Responses of caged red-winged blackbirds to two types of repellents. J. Wildl. Manage., 38: 418—423.

Rogers, J.G., Jr., 1978. Some characteristics of conditioned taste aversions in red-winged blackbirds. Auk, 95: 362—369.

Rogers, J.G., Jr., 1980. Conditioned taste aversion: its role in bird damage control. In: E.N. Wright, I.R. Inglis and C.J. Feare (Editors), Bird Problems in Agirculture. British Crop Protection Council, Croydon, pp. 173—179.

Rogers, J.G., Jr. and Linehan, J.T., 1977. Some aspects of grackle feeding behavior in newly planted corn. J. Wildl. Manage, 41: 444—447.

Schafer, E.W., Jr., Brunton, R.B., Lockyer, N.F. and Cunningham, D.J., 1975. The chemical toxicity of methiocarb to grackles, doves, and quail and reproductive effects in quail. Bull. Environ. Contamin. Toxicol., 14: 641—647.

Schlagbauer, B.G.L. and Schlagbauer, A.W.J., 1972. The metabolism of carbamate pesticides — a literature analysis. Part I. Residue Rev., 42: 1—84.

Shumake, S.A., Gaddis, S.E. and Schafer, E.W., Jr., 1977. Behavioral response of Quelea to methiocarb (Mesurol). Proc. Bird Control Semin., 7: 250—254.

Sokal, R.R. and Rohlf, F.J., 1969. Biometry. Freeman, San Francisco, CA.

Terhune, E.C., 1977. Components of a visual stimulus used by Scrub Jays to discriminate a Batesian model. Am. Nat., 111: 435—451.

Thompson, R.D., Grant, C.V. and Elias, D.J., 1981. Factors affecting red-winged blackbird response to methiocarb, an avian repellent. Pestic. Biochem. Physiol., 15: 166—171.

Vane-Wright, R.I., 1981. Mimicry and its unknown ecological consequences. In: P.L. Forey (Editor), The Evolving Biosphere. Cambridge University Press, Cambridge, pp. 157—168.

Wright, E.N., 1980. Chemical repellents — a review. In: E.N. Wright, I.R. Inglis and C.J. Feare (Editors), Bird Problems in Agriculture. British Crop Protection Council, Croydon, pp. 164—172.