

Imitation in Rats: Conditions of Occurrence in a Bidirectional Control Procedure

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Magazine trained rats had their first opportunity to push a joystick immediately after observing the joystick being pushed to the right or to the left by a conspecific demonstrator. When they were given direct access to the joystick, the observers were rewarded for both left and right pushes. Observers tended to push the joystick in the same direction as their demonstrators when the demonstrators' responses were immediately followed by delivery of food to the demonstrator and the presentation of a tone, but no evidence of imitation was found when the demonstrators' responses were followed by food alone, tone alone, or had no programmed consequences (Experiments 1 and 2). Imitative responding also occurred when the demonstrators' responses were partially reinforced with a programmed delay of 5 s between responding and food/tone delivery (Experiment 3). These results suggest that, in this bidirectional control procedure, imitation will not occur unless the demonstrators' responses are followed (immediately or after a delay) by both a tone and food. © 1994 Academic Press, Inc.

Imitation is regarded by many researchers as a distinctive form of learning (Churchland, 1986; Heyes, in press; Shettleworth, 1993), and yet little

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is known about the psychological processes responsible for imitation. Uncertainty as to whether nonhuman animals are capable of nonvocal imitation has formerly precluded their use to elucidate its mechanisms (Galef, 1988). Attempts to demonstrate that nonhuman animals can imitate have typically shown that rats which have observed a conspecific demonstrator making reinforced responses subsequently acquire the same response faster than controls that were exposed to a demonstrator receiving noncontingent reward, or to a passive conspecific, before testing (e.g., Levine & Zentall, 1974; Zentall & Levine, 1972). Such effects may be due to response learning by observation and therefore provide some evidence of imitation, but unfortunately other interpretations of these data are possible. They may be examples of local enhancement (Thorpe, 1956) or observational autoshaping (Hogan, 1986, 1988) in which the behavior of a conspecific directs the observer's attention to the manipulandum and thereby affects frequency of contact with the manipulandum on test, either directly or via stimulus-reinforcer learning during observation.

Two recent studies have provided relatively clear evidence of imitation using procedures in which naive animals observe trained conspecifics acting on a single manipulandum in one of two different ways. First, Galef, Manzig, and Field (1986) found that budgerigars that had observed a conspecific using its feet to lift a flat cover from the top of a food cup were subsequently more likely to use their feet to lift the cover than birds that had observed a conspecific using its beak. Second, Heyes and Dawson (1990) used a "bidirectional control" procedure, in which magazine trained rats were allowed to observe a conspecific pushing a joystick to the left or to the right with continuous reinforcement, before they were given access to the joystick for the first time and rewarded for both left and right responses. On test, the group that had observed left pushing made a greater proportion of their responses to the left than the group that had observed right pushing. The observer and demonstrator rats were face-to-face during the observation phase of the experiment, and the observers were given access to the joystick from the position previously occupied by the demonstrator. This arrangement made it unlikely that the effect reported by Heyes and Dawson (1990) was due to stimulus-reinforcer learning during observation, and subsequent experiments have apparently confirmed that demonstrator-consistent responding in the bidirectional control procedure is due to response learning by observation. In one of these experiments (Heyes, Dawson, & Nokes, 1992), observer rats pushed the joystick in the same direction, relative to their own bodies, as had the demonstrators, even when this action resulted in the joystick moving toward a different location in space.

The present experiments examined some of the conditions of imitation in rats as a preliminary to investigation of its underlying mechanisms. In previous bidirectional control experiments (Heyes & Dawson, 1990; Heyes

et al., 1992), each of the demonstrators' joystick pushing responses two programmed consequences: sounding of a tone and delivery of pellet to a tray in the demonstration compartment. Both events clearly perceptible by the observers and are likely to have had a value for the observers because, during prior magazine training contiguous occurrence signaled receipt of food by the observers. It is not clear whether these potential sources of vicarious reinforcement role in imitation by rats, in Experiments 1 and 2 observer rats exposed to one, both, or neither of the events immediately after the demonstrators' responses.

EXPERIMENT 1

Following magazine training, each subject in Experiment 1 observed a demonstrator pushing a joystick to the left or to the right before being given access to the joystick for the first time. Each of the demonstrators' joystick responses was immediately followed by delivery of food to the demonstrator and presentation of a tone (Group FOOD + TONE) or no food (Group TONE), or neither food delivery nor tone presentation (Group 0). On the basis of previous experiments, it was anticipated that the observers in Group FOOD+TONE would provide evidence of imitation by tending to push the joystick in the same direction as the demonstrators. If this effect depended on observation of the consequences of the demonstrators' action, then it would not be expected to occur in Group 0. The presence of the effect in Group FOOD and/or in Group TONE would suggest that it is sufficient for rats to observe one salient event in conjunction with the demonstrators' action, while its absence in both of these groups would indicate that the two events are jointly sufficient to support imitative performance.

Method

Subjects. Ninety-six experimentally naive, male, hooded Lister rats were obtained from Charles Rivers (UK), served as subjects. Sixty-four of these, the observers, were approximately 3 months old, and 32, the demonstrators, were approximately 5 months old. The subjects were housed in groups of three (one demonstrator and two observers) in molded plastic and metal hanging cages (34 × 32 × 21 cm), with free access to water. The rats were maintained at 85% of their free feeding body weight throughout the experiment.

Apparatus. The animals were trained and tested in four identical operant chambers, each measuring 50 × 25 × 20 cm. The walls were made of sheet metal, the ceiling of clear Perspex, and the floor was of a metal grid construction. Each chamber was divided into two compartments

on opposite sides of the partition and of the joystick, when a demonstrator made a "right" response the joystick moved to the left in the demonstrator's visual field and to the right in the observer's visual field.

Demonstrator training. Throughout the training of demonstrators for Group FOOD + TONE and Group TONE ($N = 16$), food delivery was accompanied by tone delivery. Initially, each of these demonstrators received six daily sessions of magazine training in the demonstration/test compartment from which the joystick had been removed. Thirty food pellets were delivered on a Random Time 45-s schedule in each session. Half of the animals were then trained to push the joystick to the left and half to push it to the right in 10, daily sessions. Each of these sessions terminated when 50 food pellets had been delivered. In the first session, each joystick displacement of 2.5 cm or more in the appropriate direction was followed by the delivery of a food pellet. In the second session the criterion displacement was 5 cm, and from the third session onward it was 7.5 cm. Joystick pushing was rewarded on a Variable Interval (VI) 15-s schedule in the fourth and fifth sessions and on a VI 30-s schedule in the remaining 5 sessions. To allow demonstrators to become accustomed to being observed while pushing the joystick, a "dummy observer" was placed in the observation compartment during each demonstrator's final 3 sessions of training. The dummy rats, which were about the same age as the demonstrators, had received instrumental training in the apparatus as part of a previous experiment.

Demonstrators for Group FOOD and Group 0 were trained in the same way as demonstrators for Group FOOD + TONE and Group TONE except that (1) food delivery was not accompanied by tone delivery and (2) 10 sessions of instrumental training preceded the introduction of the VI 15-s contingency. Each demonstrator performed for two observers: one in Group FOOD + TONE and the second in Group TONE, or one in Group FOOD and the second in Group 0.

Observer training and testing. Initially all observers received four daily sessions of magazine training in the demonstration/test compartment from which the joystick had been removed. Thirty food pellets were delivered on a Random Time 45-s schedule in each session, and each food delivery was accompanied by tone delivery. Before being allowed access to the joystick for the first time, each observer was placed in the observation compartment while a demonstrator pushed the joystick 50 times to the left or 50 times to the right. Each of the demonstrator's joystick responses was immediately followed by simultaneous food and tone delivery (Group FOOD + TONE), food delivery alone (Group FOOD), tone delivery alone (Group TONE), or neither food nor tone delivery (Group 0). When the demonstrator had made 50 responses, it was removed from the apparatus, and the observer was immediately transferred to the demonstration/test compartment where joystick displacements of 4 cm or more in

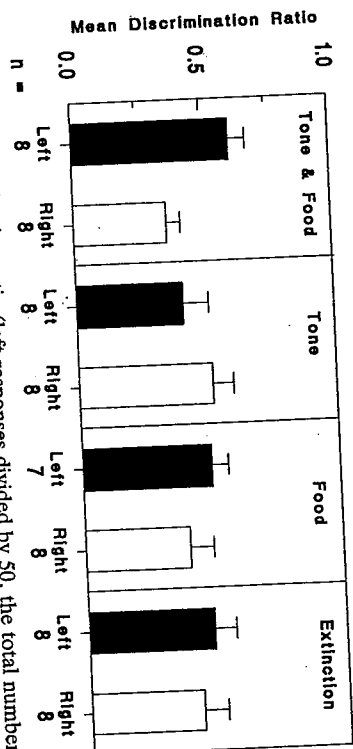


FIG. 1. Mean discrimination ratio (left responses divided by 50, the total number of test responses) for each group of observers in Experiment 1. Variance bars indicate standard errors.

either direction were immediately followed by simultaneous food and tone delivery. This test phase ended when the observer had made a total of 50 reinforced responses, or after 1 h.

Results and Discussion

One animal, which observed left responding in Group TONE, made only 14 responses on test and was therefore excluded from the analysis.

A discrimination ratio was calculated for each of the remaining observers by dividing the number of left responses by 50, the total number of responses made during the test session. These data, which are represented in Fig. 1, were subjected to preplanned contrast analysis using BMDP 4V (Hayes, 1973) comparing observers of left and right responding within each of the four treatment groups. Replicating the results of previous experiments using the bidirectional control procedure, the rats in Group TONE + FOOD tended to push the joystick in the same direction, relative to their own bodies, as had their demonstrators. The animals in this group that had observed left responding made a greater proportion of their responses to the left than rats in the same group that had observed right responding ($F(1, 62) = 5.13, p = .027$). However, the observers in the other three groups did not show a significant tendency to push the joystick in the same direction as their demonstrators (all F values < 1). The demonstrators' behavior is summarized in Table 1. In 35 of the 63 observation sessions, demonstrators showed perfect discrimination. In one of the remaining sessions the demonstrator made 20 incorrect responses in addition to the prescribed 50 right responses, and in the other 27 sessions the number of additional, incorrect responses was between 1 and 4.

On average, demonstrators made more tray entries and responded at a lower rate when they were observed by members of Group 0 than when they were observed by members of the other three groups and made

TABLE 1
Mean Discrimination Ratio (Left Responses Divided by Total Responses), Response Rate, and Tray Entry Total for Each Group of Demonstrators in Experiment 1

Group	TONE+FOOD		FOOD		TONE		EXTINCTION	
Discrimination ratio	Mean	0.50	0.50	0.13	0.48	0.12	0.50	0.12
	SEM	0.13	0.13	6.52	7.47	4.67	85.3	24.7
Response rate per minute	Mean	7.37	0.38	0.94	38.7	77.0	10.9	2.6
	SEM	0.45	0.38	38.7	7.0	24.7		
Tray entry total	Mean	65.6	77.0	38.7	7.0	24.7		
	SEM	2.6	10.9	7.0	24.7			

Note. SEM, standard error of the mean.

relatively few tray entries when observed by members of Group TONE. However, these differences are unlikely to be responsible for group differences in observers' behavior because neither response rate ($F(1, 54) = 0.38$) nor tray entry ($F(1, 4) = 1.65$) indices of demonstrators' performance covaried with observers' discrimination ratio.

The results of Experiment 1 suggest that observation of the consequences of the demonstrators' actions plays some role in generating imitative performance in the bidirectional control paradigm. They further suggest that, at the parameter values applied in Experiment 1, exposure to tone and food delivery immediately following each joystick response is sufficient to support imitative performance, while exposure to one of these events is not.

EXPERIMENT 2

Experiment 2 was a partial replication of Experiment 1 in which rats that had received six, rather than four, magazine training sessions observed a demonstrator pushing the joystick to the left or to the right with each response immediately followed by tone and food delivery (Group FOOD+TONE) or tone delivery alone (Group TONE). It was anticipated that the two additional magazine training sessions would enhance the reinforcing properties, or value, of the tone for the observers and thereby increase the probability of imitative performance in Group TONE. If additional magazine training were to result in imitation in Group TONE, it would suggest that the effect of observing the consequences of demonstrators' actions depends on the value of these events for the observer, and not merely on their perceptual salience.

Method

The method used in Experiment 2 was the same as that of Experiment 1 except in the following respects.

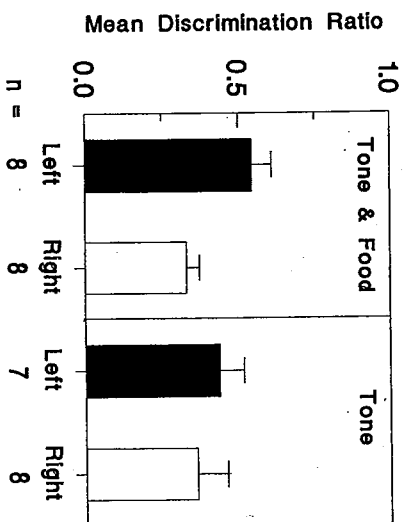


Fig. 2. Mean discrimination ratio (left responses divided by 50, the total number of test responses) for each group of observers in Experiment 2. Variance bars indicate standard errors.

Subjects. The 32 observers were approximately 4 months old, and the 16 demonstrators were approximately 8 months old, at the time of testing.

Procedure

Initially all observers received six daily sessions of magazine training. While being observed, each of the demonstrator's joystick responses was immediately followed by simultaneous food and tone delivery (Group FOOD+TONE) or by tone delivery alone (Group TONE).

Results and Discussion

One animal, which had observed left responding in Group TONE, made only 17 responses on test and was therefore excluded from the analysis.

The data were analyzed in the same way as in Experiment 1 and similar results were obtained. The observers' discrimination ratios are represented in Fig. 2. Rats in Group FOOD+TONE that observed left responding made a greater proportion of left responses than those that observed right responding ($F(1, 31) = 4.35, p = .047$), but there was no difference between the proportions of left responses made by observers of left and right responding in Group TONE ($F < 1$).

In 16 of the 31 observation sessions the demonstrators showed perfect discrimination, and in the remaining sessions they made between one and six incorrect responses. As in Experiment 1, the demonstrators responded at comparable rates when observed by Group FOOD+TONE ($\bar{X} = 9.56, SEM = 0.73$) and by Group TONE ($\bar{X} = 10.09, SEM = 1.15$) and made fewer tray entries when observed by Group TONE ($\bar{X} = 21.6, SEM = 3.19$) than when observed by Group FOOD+TONE ($\bar{X} = 65.5, SEM$

$= 1.77$). The tray entry index of demonstrator performance did not covary with observers' discrimination ratio ($F(1, 26) = 1.86$).

These results replicate and confirm those of Experiment 1, suggesting that, while observation of the consequences of a demonstrator's actions contributes to imitative performance, tone consequences are insufficient to support imitation, even when the observer has had ample opportunity to learn an association between the tone and food.

EXPERIMENT 3

Experiments 1 and 2 showed that, in the bidirectional control paradigm, exposure to stimuli consequent upon a demonstrator's action plays some role in supporting imitation of that action. The purpose of Experiment 3 was to establish whether these stimuli are effective when they are not maximally contiguous with the demonstrators' responses. After magazine training, each rat in Experiment 3 observed a demonstrator pushing a joystick to the right (Group RIGHT) or to the left (Group LEFT) when the programmed consequences of the demonstrators' responses were the delivery of food and presentation of a tone 5 s later.

Method

The method used in Experiment 3 was the same as that of Experiment 1 except in the following respects.

Subjects. The 16 observers were approximately 4 months old, and the 16 demonstrators were approximately 6 months old at the time of testing. They were housed in groups of four (two demonstrator-observer pairs).

Procedure

Demonstrator training. The demonstrators received 10, daily sessions of instrumental training in which either left ($n = 8$) or right ($n = 8$) responses were immediately and continuously reinforced by food and tone delivery. When observed, the demonstrators were experiencing delay of reinforcement for the first time.

Observer training and testing. Each observer was exposed to a demonstrator making 50 left (Group LEFT) or 50 right (Group RIGHT) responses that resulted in the delivery of food and a tone 5 s later. Any responses made by the demonstrator during the delay period had no programmed consequences.

Results and Discussion

One animal in Group RIGHT made only three responses on test and was therefore excluded from the analysis.

The observers' discrimination ratios are given in Fig. 3. On average, the rats in Group LEFT made a greater proportion of left responses than those in Group RIGHT ($F(1, 13) = 9.37, p = .009$).

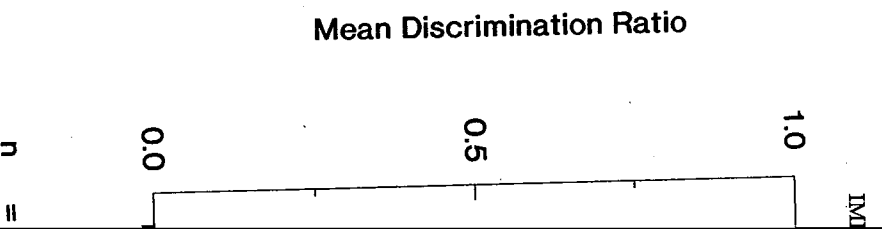


Fig. 3. Mean discrimination ratios (and SEM) for each group of observers.

Fourteen of the 15 demonstrators were observed, and the rest were observed in the incorrect direction. On average, the 14 observed demonstrators made 4.94 ($SEM = 0.58$) responses per reinforcement. The 15 demonstrators were programmed to occur during the delay period, which was programmed to occur during the delay period, which was programmed to occur during the delay period, which was programmed to occur during the delay period. Consequently, each demonstrator by means of tone delivery. Consequently, each demonstrator by means of tone delivery and the response ranged from 2.82 to 4.85 s ($SEM = 0.16$). Previous bidirectional control

Heyes *et al.*, 1992) have, like Experiments 1 and 2, provided evidence of imitation in rats when the demonstrators' responses were immediately and continuously reinforced by food and tone delivery. The results of Experiment 3 indicate that imitation may also occur when the demonstrators' responses are partially reinforced and with a delay of several seconds between responses and food plus tone deliveries.

GENERAL DISCUSSION

Experiments showing that people are more likely to imitate an action when it was followed by reward to the demonstrator than when it was followed by punishment or had no significant consequences have been interpreted as evidence that "vicarious reinforcement" is an important determinant of imitative performance (e.g., Bandura, 1965; Bandura, Ross, & Ross, 1963; Dittichs, Simon, & Greene, 1967; Kanfer & Marston, 1963; Marston, 1966). Following this example, the present experiments may be said to have shown that the magnitude of vicarious reinforcement influences imitation by rats in the bidirectional control procedure (Experiments 1 and 2) and that vicarious reinforcement need not be immediate in order to sustain imitative responding (Experiment 3). However, use of the term "reinforcement" in this context should not divert attention from the fact that, like the rewarding events presented in earlier studies of human imitation, food and tone deliveries may affect imitative performance via either an associative or a nonassociative process. The process would be associative, and the term vicarious reinforcement would be more apt, if the rats that observed food and tone deliveries learned a relationship between right or left responding and these events; a response-reinforcer relationship. The process would be nonassociative if, for example, food and tone deliveries simply attracted the observers' attention to the demonstrators' activities and thereby facilitated response learning by observation. To distinguish these possibilities with any confidence, it would be necessary to vary the contingency between the demonstrators' responses and food/tone deliveries.

To our knowledge, this is the first study of conditions of imitation learning in nonhuman animals, and the results imply that they are relatively limited. Imitation may not occur unless the demonstrators' responses have highly salient consequences. However, a limitation of this kind is unlikely to explain why "almost 100 years of study of social learning in animals has failed to produce a clear answer to the question of whether animals can . . . truly imitate" (Galef, 1988). The majority of published experiments seeking to demonstrate imitation in animals have failed to do so, not because they failed to show an effect of conspecific observation on behavior, but because the effect observed could have been due to stimulus enhancement or some other kind of social learning, rather than imitation (Heyes, *in press*). The bidirectional control procedure overcomes this problem and, using this procedure, the present experiments have

confirmed and extended the evidence that rats are capable of imitation. The results of previous bidirectional control studies (Heyes & Dawson, 1990; Heyes *et al.*, 1992) were replicated in Experiments 1 and 2, and Experiment 3 showed that rats imitate joystick pushing movements not only when their demonstrators' responses were continuously and immediately reinforced, but also when they were intermittently reinforced and after a delay.

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