

***DOES “MUTUAL REINFORCEMENT” FUNCTION AS
REINFORCEMENT?***

**¿EL “REFORZAMIENTO MUTUO” FUNCIONA COMO
REFORZAMIENTO?**

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Abstract

A contingency under which a response by an individual yields a reinforcer delivered to another individual, and vice versa, sometimes has been called mutual reinforcement. The present experiments examined whether such so-called mutual reinforcement increases and maintains response rates. Following hopper training, two pairs of pigeons were exposed to a schedule of mutual reinforcement: a peck of the key by one pigeon permitted another pigeon to access food, and vice versa (Experiment 1). The results provided no evidence that the mutual reinforcement

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increased the response rates. In Experiment 2, a fixed-ratio 1 schedule was followed by a schedule of mutual reinforcement for two pairs of pigeons. Although response rates decreased to near zero across the 70 sessions with the mutual reinforcement in effect, the rates were higher than those under a variable-time schedule, suggesting that mutual reinforcement did not maintain a stable rate of responding, but it did postpone extinction of the response.

Key words: social behavior, mutual reinforcement, key peck, pigeons

Resumen

Una contingencia bajo la cual la respuesta de un individuo produce un reforzador para otro individuo, y viceversa, en ocasiones se ha denominado reforzamiento mutuo. Los presentes experimentos examinaron si el llamado reforzamiento mutuo aumenta y mantiene las tasas de respuesta. Después del entrenamiento a comedero, dos pares de palomas fueron expuestas a un programa de reforzamiento mutuo: el picoteo a una tecla por una paloma permitió que otra paloma tuviera acceso a alimento, y viceversa (Experimento 1). Los resultados no proporcionaron evidencia de que el reforzamiento mutuo aumentara las tasas de respuesta. En el Experimento 2, un programa de razón fija 1 fue seguido por un programa de reforzamiento mutuo para dos pares de palomas. Aunque las tasas de respuesta disminuyeron a casi cero en las 70 sesiones con reforzamiento mutuo en efecto, las tasas fueron más altas que con un programa de tiempo variable, lo que sugiere que el reforzamiento mutuo no mantuvo una tasa estable de respuesta, pero pospuso la extinción de la respuesta.

Palabras clave: comportamiento social, reforzamiento mutuo, respuesta de picoteo, palomas.

Cooperation, competition, and exchange, which have been considered elemental instances of social behavior, occur under particular contingencies. With a cooperative contingency, all individuals receive an identical reinforcer if their responses meet a specified performance criterion. With a competitive contingency, reinforcers are distributed unequally based on relative performance (Schmitt, 1998). With a contingency of exchange or mutual reinforcement, responses by an individual yield a reinforcer delivered to another individual, and vice versa (Okouchi, 2012).

The term “mutual reinforcement” has multiple meanings. Sometimes, it is used to describe a cooperative contingency (Tan & Hackenberg, 2016). At other times (Baum, 2005, pp.214-216; Okouchi, 2012; Rao & Mawhinney, 1991; Ulrich & Mountjoy, 1972), and in the present paper, mutual reinforcement refers to the contingency of exchange.

Numerous interpersonal communications or social interactions, such as chatting, conversation, psychotherapy, teaching, and business transaction, arguably are controlled, at least in part, by mutual reinforcement (e.g., Baum, 2005, pp.214-216; Skinner, 1953, pp.359-412). Mutual reinforcement also has received empirical attention constantly for over a half-century (e.g., Boren, 1966; Hake & Vukelich, 1973; Molm, 1980; Okouchi, 2012; Rao & Mawhinney, 1991; Sidowski, 1957). However, the basic functions of mutual reinforcement remain not well understood. For example, it is still unclear whether what so often is called mutual reinforcement really *functions* as reinforcement, which is undoubtedly one of the most basic behavioral functions. Most allusions to mutual reinforcement in this article are to its structural definition, whereas the experimental question is whether there is experimental evidence for a functional definition of reinforcement. There has been no published work comparing responses under mutual reinforcement with those under control conditions designed to rule out other interpretations of the nominal mutual reinforcement effect. The present experiments therefore examined the reinforcement functions of “mutual reinforcement.”

One of the functions of reinforcement is to increase responding (Catania, 2013, p.460). To test this function, Experiment 1 examined whether pigeons' key pecking could be acquired under conditions of mutual reinforcement. Response acquisition is the transition from operant-level to steady-state responding (Sidman, 1960, pp.117-119; Snyckerski, Laraway, Huitema, & Poling, 2004). In laboratory settings, responses usually are acquired by shaping. If their operant levels are not zero, however, responses can be acquired in the absence of shaping even when reinforcement is delayed (e.g., Lattal & Gleeson, 1990). If the rate of key pecking under mutual reinforcement became higher than that under a schedule of response-independent reinforcement for pigeons that had no history of shaping of the key pecking, it could be concluded that mutual reinforcement actually was functioning as reinforcement.

Response maintenance is a second function of reinforcement (Catania, 2013, p.460). Some of the schedules of intermittent reinforcement do not increase the rate of responding from the operant level. However, if such schedules are introduced when the responding has become frequent by shaping and exposure to other re-

response-dependent reinforcement schedules, it is common for responding to stabilize at a certain rate. For example, Ferster and Skinner (1957, pp.332-339) reported that a pigeon's pecking was maintained at a certain rate under a variable-interval 3-min schedule after exposure to a fixed-ratio (FR) 1 schedule. Experiment 2 examined whether pigeons' key pecking was maintained by mutual reinforcement when the mutual reinforcement was transitioned from an FR 1 schedule.

With the exception of Boren (1966), there are few hints as to what the effect of mutual reinforcement on responding might be. Probably because of the exclusive use of humans as subjects, functional mutual reinforcement obtained (a) when the response was established by instructions (e.g., Sidowski, 1957), (b) by complicated procedures such as having at least some of the individual's reinforcers be dependent on the individual's own responses (e.g., Hake & Vukelich, 1973), or (c) with a short exposure to the contingency, such as a maximum of two 30-min sessions (Okouchi, 2012), each of which preclude the reliable and valid assessment of whether the response rate was systematically increased or maintained by mutual reinforcement. Boren's macaque monkeys (named Fib and Moll) first were trained to press a lever under an FR 1 with a variable delay ranging from 1 to 30 s in effect. The variable delays of reinforcement were introduced so that the monkeys' responding could persist with such delayed reinforcement that was considered likely to occur under mutual reinforcement. Thereafter, the monkeys were exposed to a mutual reinforcement condition such that when Fib pressed a lever, Moll received a food pellet, and vice versa. During about 40 sessions with the mutual reinforcement contingency in place, response rates for both monkeys decreased to very low levels. By contrast, when a timeout contingency was added to the mutual reinforcement contingency for another pair of monkeys (named Si and Al), that is, a response by one monkey during *the turn* for another monkey to respond produced a timeout for both monkeys, high rates of responding were maintained. Boren's results seem to predict that, aside from the addition of the timeout contingency (Boren called it an "alternation procedure"), the basic mutual reinforcement contingency did not maintain responding, that is, mutual reinforcement did not function as reinforcement. Because Boren did not include needed control conditions, however, it is unknown whether the response rates under that contingency were indifferent from those under similar reinforcer-delivery conditions in the absence of the response-reinforcer dependency, that is, response-independent reinforcement. Thus, Boren's results provide no evidence of whether mutual reinforcement functions as reinforcement or not. The present experiments, by contrast, examined whether mu-

tual reinforcement functions as reinforcement by comparing response rates under the mutual reinforcement with those under a control condition, a yoked schedule of response-independent reinforcement.

Experiment 1

Method

Subjects. Four male homing pigeons were maintained at about 80% of their free-feeding weights by feeding, when necessary, after a session. Water, oyster shells, and grit were freely available in the home cage. All pigeons had prior experience of pecking white stimuli on a touch screen maintained by different schedules of reinforcement, but none had experience pecking keys. The pigeons were assigned to dyads randomly. Pigeons 1a and 1b were paired, as were Pigeons 2a and 2b. The first pair of pigeons will be referred to hereafter as *Pair 1* and the second pair as *Pair 2*.

Apparatus. Two standard operant conditioning chambers, 31.5 cm wide, 31.5 cm long, 31.5 cm high, were used. One of the chambers was on the top shelf and another just below it on the bottom shelf. Sessions were conducted in the upper chamber for Pigeons 1a and 2a and in the lower chamber for Pigeons 1b and 2b. During the sessions, therefore, no visual contact could occur between the members of each pair of pigeons. Each chamber was equipped with a transparent key panel. Three clear response keys (2 cm diameter) were mounted on the panel, 8 cm apart from center to center and 22 cm above the floor. The left and right keys were not used. The center key, operated by a minimum force of about 10 g (.10 N), was transilluminated by a white 1.5-cm square presented on a black screen of a color display monitor (20 cm wide by 11 cm high), which was placed behind the front panel of the chamber. A 6 cm wide by 6 cm high aperture was located at the center of that panel, with its lower edge 3 cm above the floor. During food deliveries, when the key light was off, this aperture was illuminated by a 24-V white light and a hopper with mixed grain was presented. A house light, a white LED mounted on the ceiling of the chamber, was not used. A laptop computer with Visual Basic 2017 controlled the experiment and recorded data.

Procedure. Throughout the experiment, sessions occurred around the same time of the day, about 5 days a week. Though not experimentally naïve, the chambers used in the present experiment were novel for each pigeon. Thus, hopper train-

ing occurred individually until the pigeon ate from the hopper immediately when the hopper was raised.

Thereafter, each pair of pigeons was exposed simultaneously to a schedule of mutual reinforcement. A key peck by one pigeon allowed the other pigeon of the pair to access to food, and vice versa. Adopted from experiments that have investigated response acquisition with delayed reinforcement by pigeons (Lattal & Gleeson, 1990), the duration of food access was 8 s for Pair 1. It was, however, difficult to maintain these pigeons at 80% of their free-feeding weights, especially when they received many food deliveries, 40 in a session, for example. Thus, the duration of exposure to food was set at 3 s for Pair 2. During food deliveries to one pigeon, key pecks by the other pigeon were recorded but had no effect. Each session lasted until 40 food deliveries occurred for one of the members or 3 hr elapsed, whichever came first. Pair 1 was exposed to this mutual reinforcement condition for 25 sessions. The experiment was discontinued with Pair 2 after 14 sessions of this condition because neither pigeon responded frequently.

Following the mutual reinforcement condition, Pair 1 was exposed to a variable-time (VT) schedule for 25 sessions. The procedure in the VT condition was identical to that of the mutual reinforcement condition with the following exceptions. The frequency and distribution of response-independent food deliveries and the session duration for each pigeon were yoked to those for that pigeon in the mutual reinforcement condition. For example, the frequency and distribution of response-independent food deliveries and the session duration in Session 1 of the VT condition for Pigeon 1a were yoked to those in Session 1 of the mutual reinforcement condition for that same pigeon.

Thereafter, the mutual reinforcement condition was reinstated. We planned to expose Pair 1 to the VT condition again following this second mutual reinforcement condition, according to an ABAB design. The experiment, however, was discontinued with Pair 1 after 25 sessions of the second mutual reinforcement condition because no responses had occurred during any of the 25 sessions.

Results

Rates of responding and delivered foods were generally low. Thus, the number of responses and delivered foods per hour, not minute, were used as the measures of rates of responding and rates of food delivery, respectively. Tables 1 and 2, respectively, show the number of responses and food deliveries per hour during each session for each pigeon in the first mutual reinforcement and VT conditions.

Table 1. Number of responses per hour for each session in the first mutual reinforcement condition (and that in the yoked variable-time condition in parentheses) in Experiment 1.

Session	Pair 1		Pair 2	
	1a	1b	2a	2b
1	21.0(0.0)	43.9(0.6)	7.7	0.0
2	1.3(0.0)	60.2(0.0)	0.3	0.0
3	0.0(0.0)	15.7(0.0)	0.0	0.0
4	0.0(0.0)	6.7(0.0)	0.0	0.0
5	0.0(0.0)	5.0(0.0)	0.0	0.0
6	0.0(0.0)	7.3(0.0)	0.3	0.0
7	7.7(0.0)	75.2(1.4)	0.0	0.0
8	1.4(0.0)	11.4(0.0)	0.0	0.0
9	0.0(0.0)	5.3(0.0)	0.0	0.0
10	0.0(0.0)	5.7(0.0)	0.0	0.0
11	0.0(0.4)	5.0(0.0)	0.0	0.0
12	0.0(0.3)	1.0(0.0)	0.0	0.3
13	0.0(0.0)	0.0(0.0)	0.0	0.0
14	0.0(0.0)	2.0(0.0)	0.0	0.0
15	0.7(0.3)	0.7(0.0)		
16	0.3(0.7)	2.7(0.0)		
17	0.0(0.0)	2.0(0.0)		
18	12.9(0.7)	7.5(0.0)		
19	4.1(0.0)	21.2(0.0)		
20	4.7(0.0)	8.4(0.0)		
21	0.7(0.0)	3.3(0.0)		
22	5.8(0.0)	1.7(0.0)		
23	3.4(0.0)	5.5(0.0)		
24	0.3(0.0)	2.3(0.0)		
25	0.0(0.0)	0.7(0.0)		

Table 2. Number of food deliveries per hour for each session in the first mutual reinforcement condition (and that in the yoked variable-time condition in parentheses) in Experiment 1.

Session	Pair 1		Pair 2	
	1a	1b	2a	2b
1	26.2(26.2)	12.1(12.1)	0.0	4.0
2	51.6(51.5)	1.2(1.2)	0.0	0.3
3	13.0(13.0)	0.0(0.0)	0.0	0.0
4	6.4(6.4)	0.0(0.0)	0.0	0.0
5	4.7(4.7)	0.0(0.0)	0.0	0.0
6	7.1(7.1)	0.0(0.0)	0.0	0.3
7	62.0(61.9)	2.7(2.7)	0.0	0.0
8	10.2(10.2)	0.7(0.7)	0.0	0.0
9	5.4(5.4)	0.0(0.0)	0.0	0.0
10	5.7(5.7)	0.0(0.0)	0.0	0.0
11	5.1(5.1)	0.0(0.0)	0.0	0.0
12	1.0(1.0)	0.0(0.0)	0.3	0.0
13	0.0(0.0)	0.0(0.0)	0.0	0.0
14	2.0(2.0)	0.0(0.0)	0.0	0.0
15	0.7(0.7)	0.3(0.3)		
16	2.7(2.7)	0.3(0.3)		
17	2.0(2.0)	0.0(0.0)		
18	7.1(7.1)	9.5(9.5)		
19	13.8(13.8)	3.7(3.7)		
20	7.1(7.1)	3.4(3.4)		
21	3.0(3.0)	0.7(0.7)		
22	8.1(8.1)	5.1(5.1)		
23	3.7(4.0)	2.7(3.0)		
24	2.3(2.3)	0.3(0.3)		
25	0.7(0.7)	0.0(0.0)		

Of 25 sessions in the first mutual reinforcement condition, Pigeon 1a and 1b responded at least once during 15 and 24 sessions, respectively. During only 1 session (13) did neither pigeon respond. Of the 25 sessions in the subsequent VT condition, by contrast, Pigeon 1a responded for 5 sessions, Pigeon 1b responded for 2 sessions, and neither pigeon responded for 18 sessions. The rate of food delivery in each session of the first mutual reinforcement condition for each pigeon of Pair 1 was approximately equal to that in its yoked session of the VT condition (Table 2). These results seem to suggest that, when the rates of food delivery were equated, responses were more frequent under the mutual reinforcement contingency than that under the yoked VT schedule. In the second mutual reinforcement condition, however, neither pigeon responded at all (not shown in Table 1). Furthermore, the results of the first mutual reinforcement condition for Pair 1 were not replicated with Pair 2 (see Table 1). Of the 14 sessions in the mutual reinforcement condition, Pigeon 2a and 2b responded at least once during 3 and 1 sessions, respectively, and neither pigeon responded during 10 sessions. Thus, the results of Experiment 1 provide no evidence that mutual reinforcement increased response rate.

Experiment 2

Method

Subjects and Apparatus. The pigeons from Experiment 1 served as subjects. The apparatus was as described in Experiment 1. The center key was transilluminated by a red or green square presented on the black screen of the monitor located behind the front panel of the chamber. The hopper presentation duration was 3 s. The chamber was illuminated by the houselight throughout the session except during the hopper presentation.

Procedure. Prior to the onset of Experiment 2, that is, during the final sessions of Experiment 1, no responding occurred for each pigeon (see Table 1). Therefore, key pecking of each pigeon was initially handshaped in the presence of each of the key colors (red and green).

After shaping, an FR 1 schedule was in effect. Although each pair of pigeons was exposed to this schedule simultaneously, the schedule operated independently of its partner's behavior. That is, as is usual with an FR 1 schedule, a peck of the key by one pigeon produced food access for that pigeon. For each pigeon, a session lasted until 40 food deliveries occurred or 1 hour elapsed, whichever came first. Red and

green key lights alternated regularly every session, that is, a session with a red key light was followed by one with the green key light on. This FR 1 condition was in effect until responses to each colored key were frequent and stable as judged by visual inspection.

Finally, both pairs of pigeons were exposed to a schedule of mutual reinforcement during sessions with the red key light, and to a VT schedule during sessions with the green key light. The schedule of mutual reinforcement was as described in Experiment 1. Thus, a peck of the key by one pigeon permitted its partner access to food, and vice versa. Each session lasted until 40 food deliveries occurred for one of the members or 1 hr elapsed, whichever came first. When the VT schedule was in effect, the frequency and distribution of response-independent food deliveries and the session duration were yoked for each pigeon to those in the preceding mutual reinforcement session. This mutual reinforcement / VT condition was in effect for 140 sessions (70 sessions in each schedule) for each pair of pigeons.

Results

For both high and low response rates to be discernible on the same graph across the entire experiment, rates of responding were plotted on a log scale. Because base-10 logarithms of zero responses are undefined and such cases were not infrequent, each datum was transformed by adding one. Figure 1 shows the transformed number of responses per hour for each pigeon in each session of the FR 1 and the mutual reinforcement / VT conditions.

The FR 1 condition was in effect for 20 sessions (10 sessions with each key color) for Pair 1 and for 26 sessions (13 sessions with each key color) for Pair 2 (Figure 1). Under the FR 1 schedule, each pigeon responded steadily and frequently to both key colors. There was no systematic difference in response rates between key colors. These FR 1 results demonstrate (a) that the present apparatus and procedure were sound for operant conditioning experiments, that is, the absence of or minimal responding observed in Experiment 1 was a function of the contingencies in place and not some deficit in the apparatus per se, and (b) that frequent responding was established, which permits an examination of the research question of Experiment 2 of whether mutual reinforcement could maintain responding.

Figure 2 shows the number of food deliveries per hour for each pigeon in each session of the FR 1 and the mutual reinforcement / VT conditions. As in Figure 1, each datum was transformed by adding one. For each pigeon, the rate of food deliveries in each session under the mutual reinforcement was approximately equal

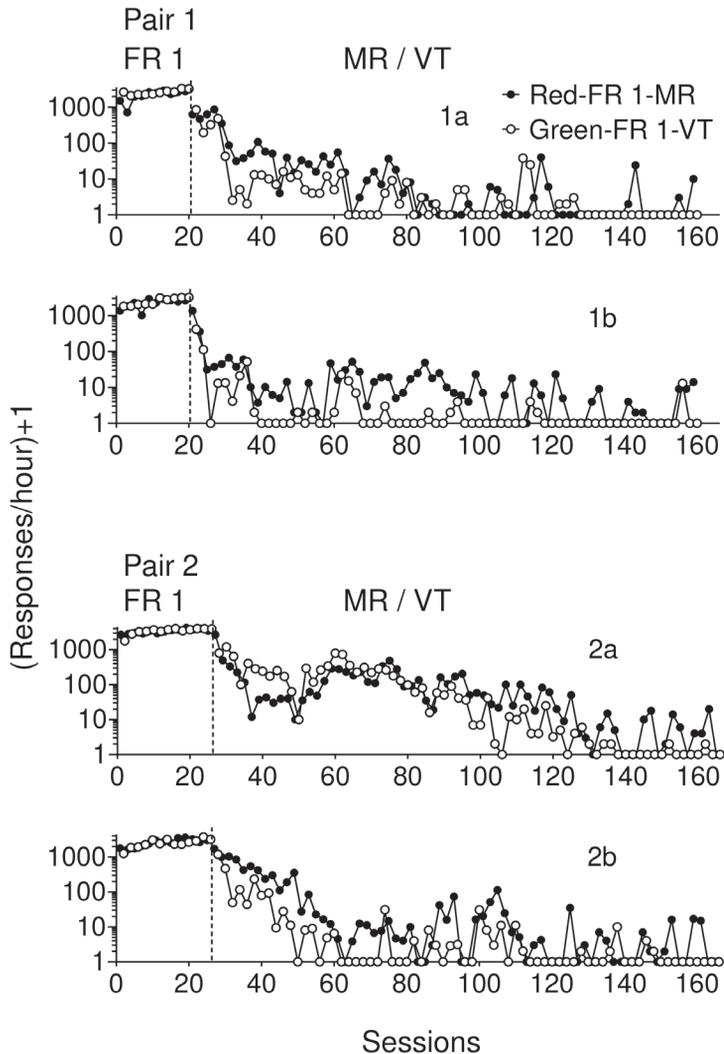


Figure 1. Number of responses per hour during each session in Experiment 2. Each datum was transformed by adding one (see text for explanation). Therefore, values on the x-axis mean that the actual rates are zero. The y-axis is presented on a log scale. Pigeons 1a and 2a were paired, as were Pigeons 2a and 2b. Filled circles represent responding when the key was red. Open circles represent responding when the key was green. During the condition labeled FR 1, a fixed-ratio 1 schedule was in effect regardless of the key color. The MR / VT label identifies the mutual reinforcement / VT condition during which a schedule of mutual reinforcement was in effect when the key was red (filled circles) and a variable-time schedule was in effect when the key was green (open circles).

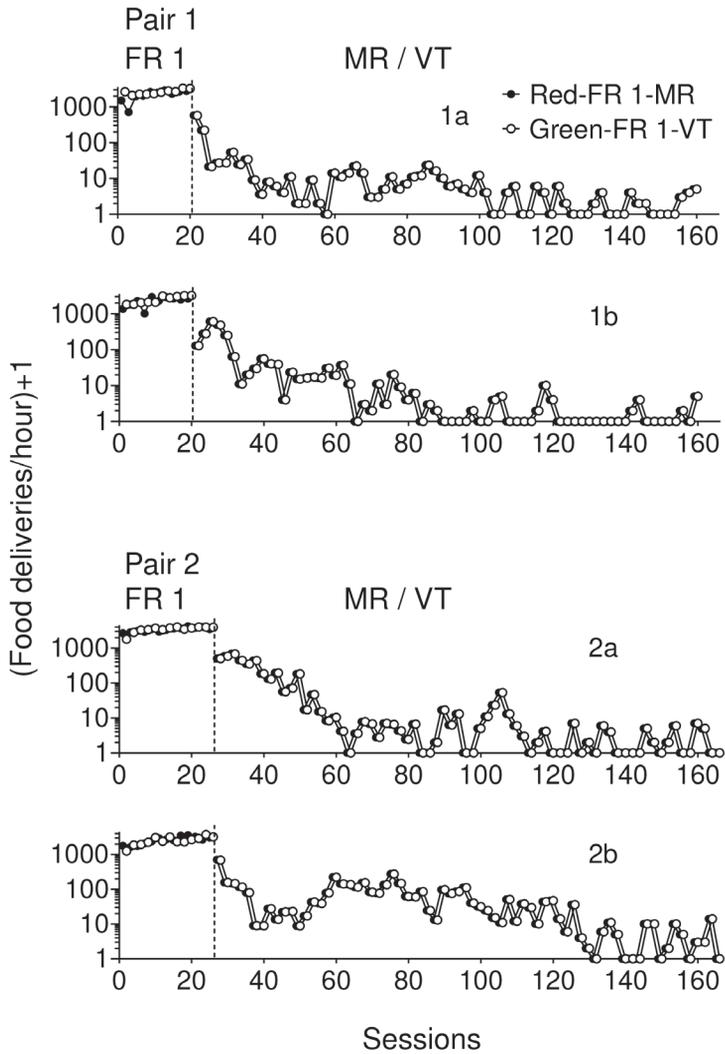


Figure 2. Number of food deliveries per hour for each session in Experiment 2. Details are as in Figure 1.

to that in its subsequent yoked session under the VT schedule. This result indicates that the rates of delivered foods were actually equated between the mutual reinforcement and yoked VT sessions.

When the mutual reinforcement contingency was introduced, response rates decreased immediately (Figure 1). The rates under the mutual reinforcement, however, were not reduced to the level of those under the VT schedule. Because the rates had decreasing trends and every mutual-reinforcement session was followed by its yoked VT session, comparisons of the rates only between the mutual reinforcement sessions and their yoked sessions could yield a misleading conclusion. Thus, the response rate in each mutual reinforcement session was compared with those in both the preceding and subsequent VT sessions. For example, the response rate during the second mutual reinforcement session (R^{MR2}) was compared with those during the first and second VT sessions (R^{VT1} and R^{VT2}). If R^{MR2} was highest of the three (R^{VT1} , R^{MR2} , and R^{VT2}), R^{MR2} was regarded as being higher than the response rates under the VT schedule. During initial sessions, in general, the response rates under the mutual reinforcement were higher than those under the VT schedule. Out of the initial 28, 40, and 16 mutual reinforcement sessions (excluding the first mutual reinforcement session that had no preceding VT session), the numbers of sessions in which the response rates in each mutual reinforcement session were higher than those compared to both the preceding and subsequent VT sessions were 25 (89.3%), 32 (80.0%), and 16 (100.0%) for Pigeons 1a, 1b, and 2b, respectively. By contrast, the initial mutual reinforcement rates of Pigeon 2a were different from the other pigeons. Of the first 22 mutual reinforcement sessions, excluding the first mutual reinforcement session, response rates in 17 sessions were lower than those in both the preceding and subsequent VT sessions. Thereafter, this pigeon's responding under the mutual reinforcement contingency became similar to that of the others. From Sessions 32 through 50 with mutual reinforcement, the rates of Pigeon 2a in 18 of the 19 sessions were higher than those in both the preceding and subsequent VT sessions.

With continued exposure to mutual reinforcement, response rates decreased to near zero. Table 3 shows the median number of responses per hour (ranges in parentheses) for the last 10 sessions under both the mutual reinforcement and VT schedules for each pigeon. Pigeons sometimes responded under the mutual reinforcement contingency, whereas they stopped responding almost completely under the VT schedule (see also Figure 1). However, there was no systematic difference in response rates between the final 10 mutual reinforcement and VT sessions.

Table 3. Median number of responses per hour (ranges in parentheses) for the last 10 sessions when the mutual reinforcement schedule was in effect (MR) and when the variable-time schedule was in effect (VT) in Experiment 2.

Condition	Pair 1		Pair 2	
	1a	1b	2a	2b
MR	0.0 (0.0- 23.0)	1.0 (0.0- 13.1)	3.0 (0.0- 19.0)	0.5 (0.0- 16.0)
VT	0.0 (0.0- 0.0)	0.0 (0.0- 12.0)	0.0 (0.0- 1.0)	0.0 (0.0- 1.0)

General Discussion

The results of Experiment 1 provide no evidence that mutual reinforcement increases response rate. As noted above, the results under the FR 1 schedule of Experiment 2 indicate that the present apparatus and procedure were sound for operant conditioning experiments, but two procedural features specific to Experiment 1 need to be considered in interpreting the results of the first experiment. The first is the duration of the VT condition. Experiment 1 adopted a criterion based on a fixed period of time (Sidman, 1960, pp.261-262), 25 sessions in each condition. Pigeons 1a and 1b, respectively, did not respond during the last 7 and 18 sessions of the VT condition, thus assuring complete extinction of the response. This complete extinction was carried over to the next condition, the second mutual reinforcement condition, during which neither pigeon responded at all, which resulted in no exposure to the mutual reinforcement contingency. If the duration of the VT condition were shortened by using a criterion based on visual inspection, or if the mutual reinforcement and VT conditions were alternated after every session as in Experiment 2, at least both pigeons might have been exposed to the mutual reinforcement contingency after the VT exposure, and therefore, the results of the first mutual reinforcement condition might have been replicated in the second mutual reinforcement condition. The duration of the VT condition, however, does not explain why neither member of Pair 2 responded frequently during the first mutual reinforcement condition.

The second procedural feature is related to the operant level. A response with a very low operant level, even though it is not zero, may not be strengthened by rein-

forcement (Okouchi, 2009). For example, one pigeon in Experiment 1 of Lattal and Gleeson (1990) responded nine times during the first two sessions of a tandem FR 1 fixed-time 30-s schedule, but ceased responding for the next five sessions. Operant levels for the present pigeons are unknown, but Pigeon 2b responded only once over 14 sessions with the mutual reinforcement contingency in effect, suggesting that this pigeon's operant level was extremely low. For example, if one of the other pigeons with a higher operant level replaced Pigeon 2b, the results may have been different. However, the results of Experiment 2 that high response rates under the FR 1 schedule decreased to near zero when the mutual reinforcement contingency was in effect, do not support any expectation that the mutual reinforcement contingency can increase or sustain response rate above the operant level.

As described in the Introduction, Boren (1966) reported that response rates for monkeys, which had been high under an FR 1 with a variable delay in effect, decreased to very low levels over about 40 sessions of exposure to mutual reinforcement. The results of Experiment 2 for both pairs of pigeons were consistent with Boren's report. Extending the findings by Boren, which did not include the yoked VT control condition, the present results demonstrated, however, that even though response rates were decreasing, they were higher under the mutual reinforcement than those under the yoked VT schedule for all pigeons. This conclusion includes the findings with Pigeon 2a, which showed the same result as the other three pigeons only during the middle portion of 70 mutual reinforcement sessions.

In sum, the present results do not suggest that mutual reinforcement increased or maintained response rates, but they do suggest that such reinforcement postponed the extinction of responding.

The Experiment 2 data were generated under at least two potentially limiting conditions. First, although the mutual reinforcement and VT schedules alternated 70 times, the stimuli correlated with these schedules were not changed. That is, throughout the experiment, the mutual reinforcement and the VT were in effect when the key lights were red and green, respectively. This procedure raises the possibility that the results may have been an artifact of key-color bias or sensory superstition (Morse & Skinner, 1957). However, the consistently higher response rates under the mutual reinforcement contingency for each pigeon, including those during the middle sessions for Pigeon 2a, seem unlikely to be produced by such adventitious variables.

The second possible limitation of Experiment 2 concerns physical contacts between the members of each pair of pigeons. The present data were obtained when

no visual contact occurred between the members. This procedural feature may raise a question of whether the present experimental situation was social or not. Schmitt (1998) defined social behavior as behavior which causes or effects include the behavior of others. Tan and Hackenberg's (2016) definition is similar to Schmitt's: behavior controlled by stimuli which include those arising from the behavior of other animals. The behavior of the present pigeons was affected by contingencies in which food deliveries were determined by the behavior of their partners. Thus, the present procedure functioned as social according to the definitions of both Schmitt and Tan and Hackenberg.

A next step of the experimental analysis of mutual reinforcement might be to better understand how mutual reinforcement postpones the response extinction. Okouchi (2012) analyzed relations between responses and consequences (points exchangeable for money) under a mutual reinforcement contingency in humans and found that points often were delivered following a delay from the last response or following no response. Similar results were found in the initial sessions of Experiment 2 with the mutual reinforcement contingency in effect for Pair 1, during which response rates were higher than those under the VT schedule for each pair member. The percentages of the number of interfood intervals (IFIs) having no response compared to the number of all IFIs during the first 10 mutual reinforcement sessions of Experiment 2, for example, were 59.3 and 76.7 for Pigeons 1a and 1b, respectively. There were responses in the other IFIs, of course, but these also resulted in long response-food intervals (i.e., reinforcement delays). The median response-food intervals of those first 10 mutual reinforcement sessions were 6.4 s and 8.9 s, respectively, for Pigeons 1a and 1b. Stimuli presented independently of responses are not reinforcing very much even including the possibility of adventitious reinforcement and those presented dependent on responses with a delay provide relatively weak effectiveness as a reinforcer (e.g., Lattal, 1995, 2010). Thus, it would be interesting to examine how the actual (i.e., functional as opposed to formal) contingencies produced by the mutual reinforcement affect the responding. The contingencies obviously are not simple. During earlier sessions in the mutual reinforcement / VT condition of Experiment 2 for Pigeon 2a, for example, response rates under the mutual reinforcement generally were lower than those under the VT schedule. Although it is unknown how the mutual reinforcement contingency contributed to this lower responding, some incidents of food deliveries following no response may have functioned to differentially reinforce other behavior.

Identifying variables that contribute to maintaining response rate also may be a future research direction of the experimental analysis of mutual reinforcement. One of the findings of the present experiments - that the mutual reinforcement did not maintain responding - is inconsistent with the suggestion that many social interactions are maintained, to some extent, by mutual reinforcement (e.g., Baum, 2005, pp.214-216; Skinner, 1953, pp.359-412). Boren (1966) anecdotally demonstrated that the alternation procedure (a mutual reinforcement contingency with a limitation that a response by an individual during the turn for another individual to respond produces a timeout for both individuals) maintained responding for both members of the pair of monkeys. Systematic analyses for answering questions about this alternation procedure, such as whether the results could be replicated by other species and procedures, may provide further insight into social interactions characteristic of human daily activities.

In conclusion, does mutual reinforcement function as reinforcement? If elements of reinforcement functions are limited to increasing and maintaining responding, the present results do not suggest that the “mutual reinforcement” functioned as reinforcement. The present results, by contrast, demonstrate that mutual reinforcement may function to increase resistance to extinction, which suggests that it does operant responding. If response strengthening is also an element of reinforcement functions (cf. Nevin, 1974, 1979), therefore, it is possible to conclude that, at least in this limited sense, mutual reinforcement does function as reinforcement.

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