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AN ANIMAL MODEL OF THE INTERPERSONAL COMMUNICATION OF INTEROCEPTIVE (PRIVATE) STATES

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Pigeons were taught to interact communicatively (i.e., exchange discriminative stimuli) based on 1 pigeon's internal state, which varied as a function of cocaine, pentobarbital, and saline administration. These performances generalized to untrained pharmacological agents (*d*-amphetamine and chlordiazepoxide) and were observed in the absence of aversive stimulation, deprivation, and unconditioned reinforcement. The training procedure used in this study appears similar to that by which humans learn to report on (tact) their internal environments and may be construed as a rudimentary animal model of the interpersonal communication of private events.

Key words: private events, tacts, interanimal communication, emotion, pigeons

Roger Schnaitter (1978) has defined *private events* as "[t]hose phenomena of psychological interest taking place 'inside the skin,' at a covert level, observable beyond the first person by indirect means, if at all" (p. 1). The present experiment investigated the role of experimentally manipulated private events in setting the occasion for communicative behavior between nonhuman organisms. The aims of this study were to determine whether nonhuman animals could learn to interact communicatively (i.e., exchange discriminative stimuli with each other), based on events in their internal milieu, report on similar internal (private) events that had not been involved in training, and whether performance on these tasks could be observed in the absence of a primary establishing operation (i.e., without aversive stimulation or deprivation) and unconditioned reinforcement.

That it is possible to teach chimpanzees (Fouts, 1973; Gardner & Gardner, 1971; Rumbaugh, 1977) and gorillas (Patterson, 1978) to interact by exchanging discriminative stimuli that are arbitrarily matched with some feature of their external environment is clear. Although there is disagreement as to whether such exchanges constitute truly linguistic activity (Brown, 1970; Premack & Woodruff, 1978; Terrace, Petitto, Sanders, & Bever, 1979) there is little doubt that basic elements of symbolic representation of meaning (Gardner & Gardner, 1984) and rudiments of early human child semantics have been taught to nonhuman primates (Gardner & Gardner, 1975; Savage-Rumbaugh, 1984). For example, Savage-Rumbaugh, Rumbaugh, and Boysen (1978) taught chimpanzees to use pictorial stimuli to report to other chimpanzees the presence or absence of the actual objects in a nearby room, to which only one animal had visual access. Moreover, limited elements of such interanimal exchanges have also been taught to pigeons (Epstein, Lanza, & Skinner, 1980; Lubinski & MacCorquodale, 1984). The present study grows out of the latter work with substitution of *private* interoceptive stimuli for exteroceptive stimuli as the stimulus source for exchange between animals.

This study is based on recent findings revealing that laboratory animals can be conditioned to emit *tacts*. A tact is defined as "a verbal operant in which a response of a given form is evoked (or at least strengthened) by a particular object or event or property of an object or event" (Skinner, 1957, pp. 81-82). As verbal operants, tacts are not maintained by particular reinforcers, nor do they covary

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with the subject's state of deprivation or aversive stimulation; they are often maintained by *generalized conditioned reinforcers* (i.e., stimuli that were initially neutral but have accrued reinforcing efficacy through pairing with two or more unconditioned reinforcers) (cf. Catania, 1984; MacCorquodale, 1969; Segal, 1977; Skinner, 1957; Winokur, 1976). Tacts are distinguished from *mands* (a more primitive class of verbal behavior) defined as "a verbal operant in which the response is reinforced by a characteristic consequence and is therefore under the functional control of relevant conditions of deprivation or aversive stimulation" (Skinner, 1957, pp. 35–36).

Verbal operants meeting the formal requirements of tacts have been conditioned in both chimpanzees (Savage-Rumbaugh, 1984) and pigeons (Lubinski & MacCorquodale, 1984). However, subjects in those studies were trained to tact exteroceptive stimuli (geometric figures, pictures, colors, letters, etc.). In the present research, nonhuman animals were conditioned to tact interoceptive stimuli. Their tacts were reinforced with a generalized conditioned reinforcer: a flashing light paired with both food and water reinforcement (under both reinforcer-relevant deprivation conditions and when satiated).

Skinner (1953, 1957, 1974) and others have explored the role private events may play in modulating overt (verbal and nonverbal) behavior (cf. Moore, 1980, 1984; Schnaitter, 1978). In one of his more important papers, Skinner (1945) provided an interpretation of the manner in which humans learn to report on private events (which are not accessible to the verbal community for confirmation). However, the systematic laboratory study of interoceptive stimuli regulating behavior has its roots in early work by Pavlov and his colleagues (Razran, 1961). Subsequently, several investigators demonstrated that animals could learn to respond differentially to the internal state produced by a psychoactive drug versus the internal milieu associated with a vehicle (usually saline) injection (Schuster & Brady, 1964; Thompson & Pickens, 1971).

In typical drug discrimination studies with nonhumans, a food-deprived animal is injected with a training drug (e.g., morphine) and is given the opportunity to press one of two levers, or peck one of two keys, leading to food reinforcement (the drug cue lever), or a second lever which produces no reinforcement (the vehicle lever). On intervening days the animal receives a vehicle injection, in which the opposite response is defined as correct, and presses on the drug lever are unreinforced. This procedure leads to rapid learning to respond only to the drug-correlated lever on days the training drug has been administered and on the alternate lever on days the vehicle has been administered. An array of psychoactive drugs produces differential responding based on interoceptive stimulus conditions (Colpaert, 1978; Griffiths, Roache, Ator, Lamb, & Lukas, 1985; Holtzman, 1985; Overton, 1977). Moreover, by using as the training compound a drug known to occupy a specific neuroreceptor, these methods have permitted rapid and precise identification of the types of neurochemical receptors occupied by a test drug, which has been confirmed by isolated tissue assays (Woods, Young, & Herling, 1982).

In the present study pigeons were trained to differentially peck three keys in relation to saline or one of two drugs, using a procedure similar to that described by France and Woods (1985). The birds were then taught to exchange arbitrary discriminative stimuli correlated with the agent that had been administered on a given day. In a second phase, generalization to related internal drug states (and the associated exteroceptive discriminative stimuli) was tested. Finally, communicative exchanges were evaluated without a primary establishing operation and unconditioned reinforcement.

METHOD

Subjects

Subjects were 5 experimentally naive female white Carneau pigeons (*Columba livia*) divided into two groups, referred to as "manders" (2 birds) and "tacters" (the remaining 3). Although our subjects' behavior will not meet all of the defining features of mands and tacts until later in the experiment, we will refer to them as manders and tacters from the outset. All animals were housed in individual cages located in a constantly illuminated vivarium, with temperature maintained at 25 ± 1° C. Gravel was constantly available in the home cage, and food and water were available following each session according to the schedule discussed below.

Apparatus

The experimental apparatus was the same as that used in the Lubinski and MacCorquodale (1984) investigation, but was modified in several ways. It consisted of two contiguous experimental chambers, separated by a 0.64-cm-thick transparent Plexiglas divider, each supplied with an individualized stimulus presentation and response panel (see Figure 1). The dimensions of each of the two compartments were 34.3 by 31.6 by 35.6 cm. The aluminum back wall of each chamber contained several translucent discs (see Figure 1), which when pecked with a force of at least 0.20 N broke the key contacts and was counted as a key peck. Keys were transilluminated with color lights (6 W, 110 vac) at indicated times (see below). Stimuli were presented (and all responses were recorded) by means of electromechanical equipment located in a nearby room. Extraneous sounds were attenuated by a continuously operating fan, and solenoid-operated delivery mechanisms were used for reinforcement with food and water. Experimental sessions were conducted 7 days per week. The manders were trained in the left chamber, the tacters in the right. Each subject's playing of one of two parts (i.e., mander or tacter, shown in Table 1) was first individually conditioned according to the following procedure.

General Procedure

Training tacters. The tacters were initially trained in a complex two component chain: The first component involved a three-key cross-modal matching-to-sample discrimination (composed of interoceptive sample stimuli matched to exteroceptive counterparts). The second component comprised a two-key nonreversible option (Findley, 1962), whereby all pecks on the food and water keys were reinforced under a continuous reinforcement schedule with their corresponding reinforcers.

In the first step of the tacters' training, the birds, which were either 28 hr food deprived and 4 hr water deprived *or* 28 hr water deprived and 4 hr food deprived (these two conditions alternated in an A-B-A-B fashion), were trained to peck the food and water keys. Pecks on the water key made available 0.4 mL of water for 4 s, whereas pecks on the food key provided access to mixed grain for 4 s. These responses were reinforced only when a blue light was flashing (see Figure 1). This was to establish the flashing blue light as a generalized conditioned reinforcer (Lubinski & MacCorquodale, 1984; Savage-Rumbaugh, 1984; Segal, 1977; Skinner, 1957). Approximately 6 weeks from the first adaptation session were required for the flashing blue light to consistently control subjects' pecking of the food and water keys.

The tacters were then trained to produce the flashing light by pecking response keys labeled with letters representing "Depressant," "Stimulant," and "No drug," after receiving an intramuscular injection of either a depressant (pentobarbital 8 mg/kg), a stimulant (cocaine, 3 mg/kg) or isotonic saline (given in the same volume as the other two drug solutions), respectively. Saline was also used as the vehicle for pentobarbital and cocaine delivery. Cocaine and pentobarbital were chosen as training drugs because of their well-documented discriminative and reinforcing properties in laboratory animals (Griffiths et al., 1985; Schuster, Fischman, & Johanson, 1981) and because of the likelihood for their abuse in humans (Thompson & Unna, 1977).

Although unitary letters were projected on the subjects' response keys representing the drug and drug-class names employed in this study (see Figure 1), we will use the names of the drugs and drug classes in describing the procedure to make this section easier to follow. The specific names presented on the tacters' response keys were chosen for clarity in experimental exposition, not in an attempt to impart symbolic meaning.

Immediately following injection of one of the aforementioned agents, a tacter was placed into the darkened experimental chamber. After a 20-min interval, an overhead light was illuminated and, simultaneously, the three response keys were transilluminated. Pecks matching the birds' interoceptive state (i.e., saline injection = "No drug," pentobarbital = "Depressant," and cocaine = "Stimulant") were followed by presentation of the flashing blue light, and then a response on the food or water key was reinforced with food or water. Five key pecks were required to produce the flashing light (FR 5); if either of the two other keys was pecked five times, the overhead light and illumination behind the response keys were terminated for 4 s, after which the houselights

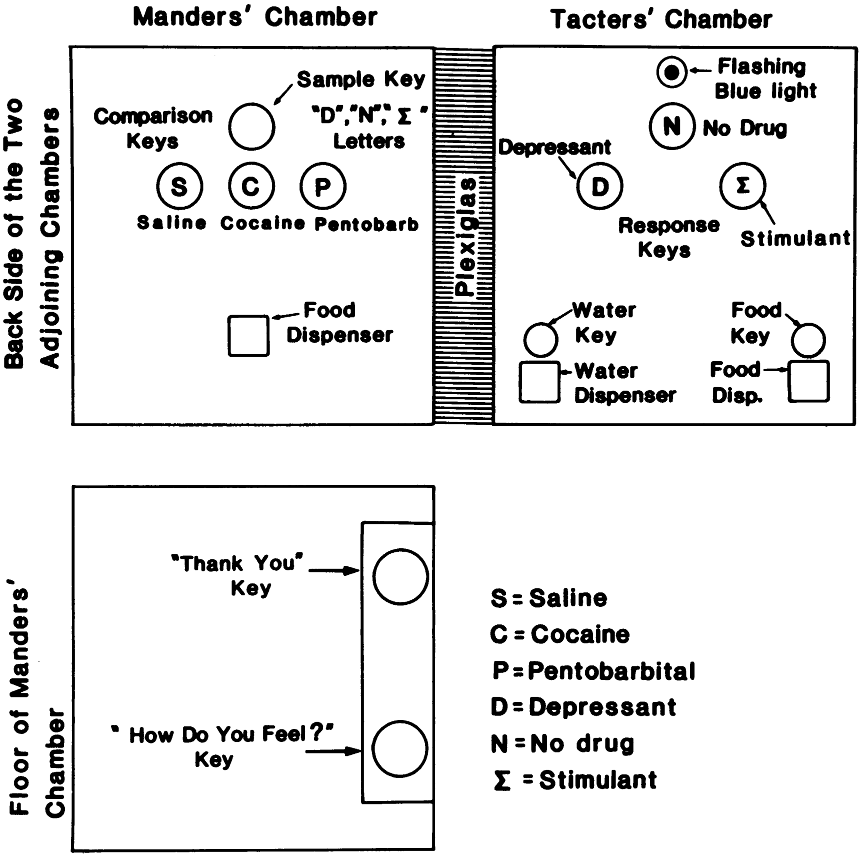


Fig. 1. Adjoining keyboards for the two groups of birds were separated by a Plexiglas divider. The manders were trained in the left chamber; the tacters were trained in the right chamber. The procedure is given in Table 1.

and response keys were reilluminated and a new trial started. Approximately 7 months were required for the tacters to respond reliably in this three-key discrimination procedure under both food and water deprivation conditions; across the final 40 sessions of this 7-month training interval, the tacters all performed with an overall accuracy of 90%, and with at least 80% accuracy in each of the six, 2(Deprivation) × 3 (Drug), conditions (with a minimum of five observations in each condition). These percentages are based on the first FR 5 emitted at the beginning of each session.

Manders' training. Four response keys confronted the manders on their control panel: three comparison keys labeled "Pentobarbital," "Cocaine," and "Saline" and a sample key, on which the drug-class names (i.e., Depressant, Stimulant, and No drug) could be projected (see Figure 1). The body weights of both manders were maintained at 85% of their free-feeding values throughout the experiment. They were first trained (in a conditional discrimination) to match the comparison keys labeled "Pentobarbital," "Saline," and "Cocaine" to the drug-class names projected on their sample keys: "Depressant," "No drug," and "Stimulant," respectively. Thus, they were taught to match drug-class names (to specific drug names) by pecking response keys containing names of the specific drugs.

Training consisted of quasirandomly projecting the names of the three drug classes (Depressant, No drug, and Stimulant) onto the manders' sample key. Pecking the sample key when a drug-class name was projected onto it and then pecking the response key containing the correct matching response (i.e., Depressant = Pentobarbital, Stimulant = Cocaine, and No drug = Saline) was reinforced with 4-s access to mixed grain. After the birds became

90 to 95% proficient at this task, two additional requirements were added: The manders could produce the drug class names on the sample key only by (first) pecking an illuminated key located at floor level (Figure 1) labeled "How do you feel?" and (second) pecking a floor key labeled "Thank you."

The manding performance involved a three-component chain: The terminal link was an arbitrary matching-to-sample task, whereas the preceeding two components (first, pecking the "How do you feel?" key, and second, pecking the "Thank you" key) were reinforced under a continuous-reinforcement schedule.

At this point during the training sequence, individual subjects in both groups had independently acquired the necessary component repertoire for an interanimal interaction based on the tacters' interoceptive state. Individual tacters and manders were placed in their chambers simultaneously and access to each component of the communicative exchange was made contingent on the other bird's behavior (see Table 1). (Before placing pairs of birds into the experimental apparatus to perform the interaction, an adaptation manipulation was conducted. Pairs of birds, composed of one mander and one tacter, were placed in their respective chambers concurrently, with only the houselights and the noise-attenuating fan operating. Each adaptation session lasted 45 min and all birds experienced at least four such sessions.)

PHASE 1: THE INTERANIMAL INTERACTION

Procedure

The interaction sequence began when the mander pecked its "How do you feel?" key. This response illuminated the drug-class names on the tacter's three response keys (i.e., "Depressant," "No drug," and "Stimulant"). The tacter then pecked the response key corresponding to the drug it had received. This response illuminated the "Thank you" key in the mander's chamber. When the mander pecked the "Thank you" key, two events ensued concurrently: The tacter's blue light began to flash and the drug-class name previously pecked by the tacter appeared on the mander's sample key. At this point the remainder of the response sequence of the 2 birds were independent of each other. With the blue light flashing, the tacter could receive food or water by pecking the appropriate key, and the mander could receive food by correctly matching the specific drug (among its comparison response keys) to the drug class (on its sample key) (see Table 1).

Table 1

The complete verbal episode.

	Component 1
Mander:	The mander's "How do you feel?" key is illuminated and the mander pecks it, which advances the sequence to Component 2.
	Component 2
Tacter:	All three of the tacter's response keys are illuminated simultaneously. It pecks the response key correlated with its state (i.e, cocaine state = Stimulant, pentobarbital state = Depressant, and saline state = No drug). If the bird pecks a noncorresponding key, the houselights in its chamber are dimmed for 4 s and the conditions of Component 1 are reinstated. Pecking the corresponding key advances the sequence to Component 3.
	Component 3
Mander:	The "Thank You" key in the mander's chamber is illuminated. The mander pecks the "Thank You" key, which advances the sequence to Component 4.
	Component 4
Mander:	The drug name previously pecked by the tacter appears on the mander's sample key.
Tacter:	The blue light begins to flash in the tacter's chamber.
	Component 5
Mander:	The mander matches the drug-class name projected on its sample key (i.e., it pecks the drug class) and the appropriate drug (Stimulant = Cocaine, Depressant = Pentobarbital, or No drug = Saline). This response is reinforced with mixed grain. If the mander errs, the overhead houselights in its chamber are dimmed for 4 s and the conditions of Component 1 are reinstated. At the end of this component (i.e., after the mander has produced a reinforcer or finishes a timeout), the conditions of Component 1 are reinstated, and the cycle continues.
Tacter:	The tacter receives either mixed grain or water by pecking the appropriate key (after reinforcement the blue light stops flashing). On satiated days, it receives only the flashing light; the blue light stops flashing when the conditions of Component 1 are reinstated by the mander.

Before each interaction, manders were given

Table 2

Percentage of correct responses for each bird and their correspondence on the first interanimal exchange across three phases. Phase 1 consists of four columns of data taken from the first trial across 40 experimental sessions: The fractions under "Deprivation" represent the proportion of correct responses by the tacters, under each of the six, 2 (food and water deprivation) × 3 (cocaine, pentobarbital, and saline), conditions. The denominator is the total number of sessions for each condition, and the numerator the total number of correct "tacts" of drug-induced internal states. Total % correct for all three conditions summed across both deprivation conditions is in the next column. The third column represents the manders' accuracy at matching specific-drug discriminative stimuli from drug-class discriminative stimuli (taken from the first trial across all three conditions on days in which the tacters first matching response was correct). Finally, the last column reflects the percentage of correct correspondence between the two birds for each drug state (i.e., the product of the manders' accuracy and the tacters' accuracy for the first trial across each condition). Phase 2: Combined performance of the three tacters and the two manders (taken from the first trial across 48 experimental sessions). Columns of fractions and percentages have the same meaning as in Phase 1, but with respect to chlordiazepoxide, *d*-amphetamine, and saline. Phase 3: The columns in this table have the same meaning as those describing Phase 2. An additional column labeled "Satiation" represents 18 sessions of tacters' performance when satiated (2 satiated sessions, for each of the three conditions, chlordiazepoxide, *d*-amphetamine, and saline, for all 3 birds).

Phase 1

Drug	Deprivation		Total % correct	Manders' accuracy (%)	Correspondence accuracy (%)
	Food	Water			
Tacter 1					
Cocaine 3 mg/kg	5/5	4/5	90	89	80
Pentobarbital 8 mg/kg	5/5	5/5	100	90	90
Saline	9/10	9/10	90	94	85
Tacter 2					
Cocaine 3 mg/kg	5/5	4/5	90	95	86
Pentobarbital 8 mg/kg	5/5	5/5	100	100	100
Saline	9/10	10/10	95	95	90
Tacter 3					
Cocaine 3 mg/kg	5/5	5/5	100	70	70
Pentobarbital 12 mg/kg	5/5	5/5	100	80	80
Saline	10/10	9/10	95	95	90

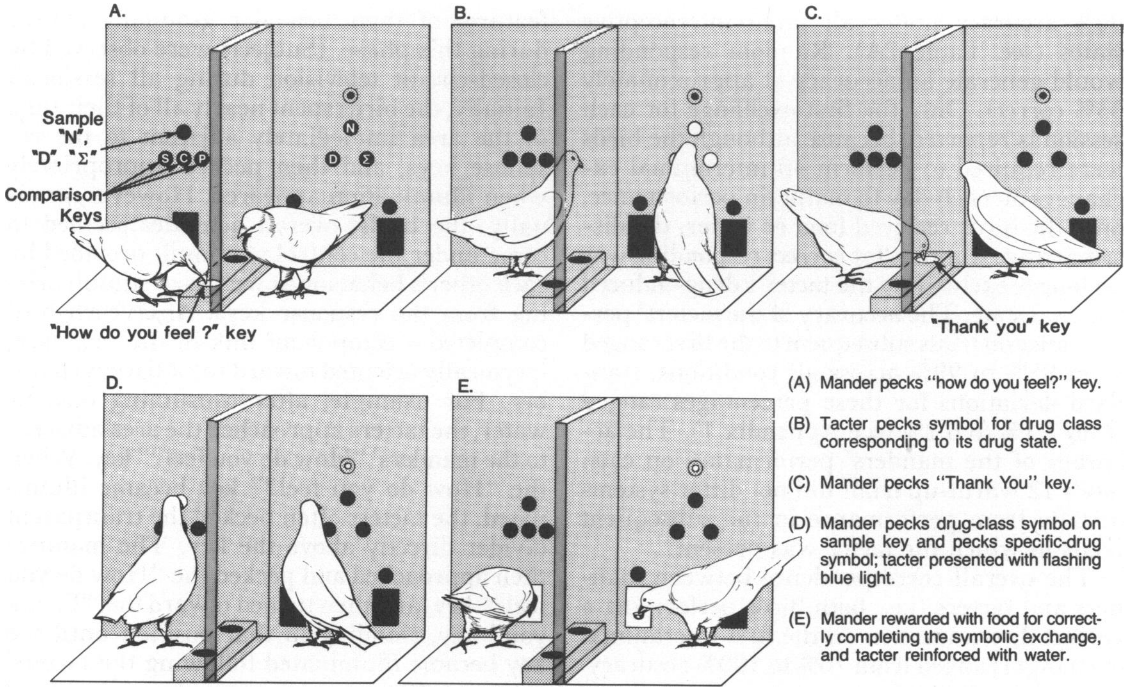
Phase 2

Drug	Tacters' deprivation (n = 3)		Total % correct	Manders' accuracy (%)	Correspondence accuracy (%)
	Food	Water			
Amphetamine 2 mg/kg	5/6	6/6	92	91	84
Chlordiazepoxide 8 mg/kg	6/6	6/6	100	92	92
Saline	10/12	11/12	88	95	84

Phase 3

Drug	Tacters' deprivation (n = 3)		Satiation	Total % correct	Manders' accuracy (%)	Correspondence accuracy (%)
	Food	Water				
Amphetamine 2 mg/kg	2/3	2/3	5/6	75	95	71
Chlordiazepoxide 8 mg/kg	3/3	3/3	6/6	100	92	92
Saline	14/15	14/15	6/6	92	97	89

12 warm-up trials of matching drug-class names to specific drug names before the tacter was placed in the adjacent chamber. Each mander performed in an equal number of interactions. Although both manders worked with all of the tacters, one worked primarily with Tacter 1, the other primarily with Tacter 3, and Tacter 2 worked 50% of the time with



(A) Mander pecks "how do you feel?" key.

(B) Tacter pecks symbol for drug class corresponding to its drug state.

(C) Mander pecks "Thank You" key.

(D) Mander pecks drug-class symbol on sample key and pecks specific-drug symbol; tacter presented with flashing blue light.

(E) Mander rewarded with food for correctly completing the symbolic exchange, and tacter reinforced with water.

Fig. 2. A 2-pigeon communicative exchange based on the internal state of one of the birds (mander, left; tacter, right). (A) The mander pecks its "How do you feel?" key. (B) The tacter pecks the drug-class letter corresponding to its internal state. (C) The mander pecks the "Thank You" key, which presents the flashing blue light to the tacter; this response also presents to the mander the drug-class letter previously pecked by the tacter. (D) The mander matches the drug-class letter (projected on its sample key) by pecking it and then pecking the letter representing the specific drug that the tacter is currently experiencing; the tacter attends to the flashing blue light. (E) The mander is reinforced with food for correctly completing the communicative exchange; the tacter is reinforced with water.

each. For individuals in both groups, the birds' accuracies did not vary as a function of with whom they were interacting. (Prior to the interanimal interaction, Tacter 3 began to show some signs of tolerance to pentobarbital. Toward the middle and end of the 40-trial period, it began pecking both the saline and pentobarbital keys and taking some timeouts; therefore, it was decided to increase its dose of this agent to 12 mg/kg. We are indebted to Sheldon Sparber for recommending this modification. After implementing this change, Tacter 3's accuracy remained high throughout the 40-trial sessions.)

On alternating days the tacters were either 28 hr food deprived and 4 hr water deprived, or 28 hr water deprived and 4 hr food deprived. Administration of the drugs and of saline alone was quasirandomized: Tacters were given free access to both food and water for 12 hr following a cocaine or pentobarbital session, and neither of these agents was given more than twice in succession (discounting days with saline alone) without the other administered once. On each experimental day, the three tacters received different injections. This measure was taken to prevent the manders from discriminating what drug condition was operating, because on every experimental day, one of the manders would perform twice and the other only once (except on the days in which only two tacters were run: on these days each mander performed once). Each session was continued until the tacter earned 40 reinforcers (either food or water). Finally, the first 2 days of the interanimal exchange are not reported in Table 2 (see below); both consisted of saline injections (one under food deprivation, the other under water deprivation) and were viewed as warm-up days (i.e., a time for the birds to adapt to working interactively).

Results and Discussion

Across 40 experimental days subjects performed this interaction with a high degree of accuracy; all three tacters performed at or above

90% accuracy under all three interoceptive states (see Table 2A). Random responding would generate an accuracy of approximately 33% correct. Only the first exchange for each session is reported, because although the birds were required to perform 40 interanimal exchanges on each day to maintain performance, once the birds received food or water, the discriminative stimulus for correct responding was no longer exclusively the tacter's drug-induced internal state. The accuracy of the tacters' performance on trials subsequent to the first ranged from 95% to 99% across all conditions; standard deviations for these percentages ranged from 2.1% to 6.2% (see Appendix 1). The accuracy of the manders' performance on each day's 12 warm-up trials did not differ systematically from performance in the subsequent trials in which the tacter was present.

The overall correspondence between manders and tacters (i.e., both birds performing a correct discrimination on the first interanimal exchange) ranged from 70% to 100% accuracy. The probability of a correct correspondence happening by chance is approximately 11% (the product of the two individual performances happening by chance, viz., .33 × .33 = .11). Approximately 15 min were required to complete 40 interanimal exchanges, across all three drug conditions (see Figure 2).

Although this may represent a unique instance of communicative exchange (via arbitrary matching tasks) between two nonhuman organisms based on the interoceptive state of one of the participants, such exchanges are familiar among humans. People often ask one another how they feel, and maintain the probability of future reporting of internal states by expressions of interest, concern, or enthusiasm about the speaker's self-reported feeling. In the present experiment, the manders' key peck responses requested information from the tacters based on the latter's internal state: tacters reinforced the manders' requests by tacting (i.e., pecking) the drug-class name (on illuminated response keys) that corresponded to their current state; the manders then reinforced those tacts by emitting a response that produced the flashing blue light and, in turn, matched the tacters' report by pecking a second class of arbitrary stimuli that corresponded to the specific drugs.

Although the birds' accuracy remained high throughout the 40 experimental days, some features of their behavior gradually shifted during this phase. (Subjects were observed by closed-circuit television during all sessions.) Initially, the birds spent nearly all of their time in the area immediately adjacent to the response keys, and then pecked appropriately when illumination appeared. However, gradually, the birds' overall activities seemed to come under the control of stimuli provided by each other's behavior as well as of stimuli arising from the response keys. After each bird completed a component link in the sequence, it typically oriented toward the adjacent chamber. For example, after consuming food or water, the tacters approached the area adjacent to the manders' "How do you feel?" key. When the "How do you feel?" key became illuminated, the tacters often pecked the transparent divider directly above the key. The manders then approached and pecked the "How do you feel?" key, and then turned toward the "Thank you" key, standing in that position until the key became illuminated following the tacters' response. If the tacters were slow in pecking the drug-class key, the manders tended to peck the transparent partition in a fashion similar to that described by Epstein et al. (1980) and Lubinski and MacCorquodale (1984). In practice, however, birds in both groups usually completed successive links within the interaction quickly, so such partition-pecking was not typical; it did occur, however, if either bird paused.

PHASE 2: GENERALIZATION TO RELATED DRUGS

Procedure

The next objective of this research was to determine whether the discriminative performances established would generalize to similar but somewhat different states (i.e., private events induced by pharmacological agents that the subjects had not experienced previously). Chlordiazepoxide (Librium®) and *d*-amphetamine (Dexedrine®) are commonly used in our culture both therapeutically and recreationally (Miller et al., 1983; Szara & Ludford, 1981). Although *d*-amphetamine and chlordiazepoxide differ chemically and pharmacologically from cocaine and pentobarbital, they both share pharmacological properties with these agents (Gilman, Goodman, Gilman, 1980). Moreover, it is well established that in conventional preparations for two-choice drug versus saline discrimination, they generalize to cocaine (Fischman, 1984) and pentobarbital (Ator & Griffiths, 1983), respectively.

The generalization test required a slight procedural modification, however. Because chlordiazepoxide is absorbed and distributed more slowly than cocaine or pentobarbital, the presession injection interval was increased to 30 min. The first 2 days of the 30 min presession injection interval consisted of saline injections (one under water deprivation, the second under food deprivation). Drug generalization tests were then conducted in the same unpredictable fashion with *d*-amphetamine administered at 2 mg/kg and chlordiazepoxide at 8 mg/kg intramuscularly in breast muscle.

Results and Discussion

Of 24 trials, six for each test agent under food and water deprivation, only one error occurred (i.e., 95.8% correct). This observations was recorded the second time the subject (Tacter 1) was exposed to *d*-amphetamine; it had responded correctly on the first exposure (see Table 2B). The accuracy of the tacters' performance on trials subsequent to the first ranged from 92% to 99% across all conditions; the average standard deviation for these percentages was 4.6% (see Appendix 2).

The tacter pecked the drug-appropriate key, reporting to its counterpart in the adjacent chamber that the interoceptive stimuli engendered by *d*-amphetamine were more similar to a cocaine state than to either saline- or pentobarbital-induced states; similarly, it reported that the interoceptive stimuli produced by chlordiazepoxide were more similar to a pentobarbital state than to a saline or cocaine state. The correspondence accuracy for this condition ranged from 84% to 92% correct—chance would be approximately 11%.

The tacters' three-key interoceptive discrimination generalized to pharmacological agents that are known to produce similar, but presumably somewhat different, internal conditions (Ator & Griffiths, 1983; Fischman, 1984). The tacters' performance is similar to that reported by France and Woods (1985). They trained pigeons to peck three response keys corresponding to the interoceptive stimulus control of morphine, naltrexone, or saline administration. After their performance was firmly established, generalization tests were conducted (using similar but nevertheless novel test stimuli, viz., naloxone, ethylketazocine, buprenorphine, and pentazocine). The opiate antagonist naloxone generalized to the naltrexone response key and the opiate agonists ethylketazocine, buprenorphine, and pentazocine generalized to the morphine response key.

Further, the present generalizations, across depressants and across stimulants, of discriminations between cocaine, pentobarbital, and saline internal states are consistent with earlier (two-choice, drug versus saline) discrimination/generalization laboratory animal studies (Ator & Griffiths, 1983; Brady & Griffiths, 1977; Griffiths et al., 1985; Johanson & Schuster, 1977). Moreover, these data are in accord with data from humans who were experienced with cocaine; these subjects did not report feeling differently when injected intravenously with 10 mg of amphetamine versus 16 mg of cocaine (Fischman & Schuster, 1980). In addition, humans treated with chlordiazepoxide report experiential effects similar to those produced by pentobarbital (Griffiths et al., 1985).

Although the present findings are consistent with earlier work, the finding that a nonhuman animal can learn to perform a discrimination of three internal states maintained by two reinforcers, under two distinctive deprivation conditions, is new. An additional unique feature of this performance is that it is contained within an interanimal communicative exchange.

PHASE 3: SATIATION AND DISCONTINUATION OF PRIMARY REINFORCEMENT

The type of communicative behavior displayed by the tacters qualifies as tacts, that is, verbal responses established with multiple reinforcers and that do not specify a particular reinforcer. In humans, tact relationships are often said to be maintained solely by generalized conditioned reinforcers (Lubinski & MacCorquodale, 1984; Savage-Rumbaugh, 1984; Skinner, 1957). In the present experiment, the generalized conditioned reinforcer was the tacters' flashing blue light. To determine whether the tacters would continue to report on their internal state when satiated with food and water and without deprivation-relevant reinforcement (but with the flashing light functioning as a generalized conditioned reinforcer contingent on discriminative responding), the following additional experimental probe was conducted.

Procedure

The same procedure described in Phase 2 for *d*-amphetamine and chlordiazepoxide was maintained; however, on every third or fourth day, the tacters were placed in their experimental chamber after receiving 24 hr free access to both food and water. Their food and water response keys were inoperative during this condition and, because of their satiated condition, they were only required to perform five interanimal exchanges rather than the usual 40.

Results

When food and water satiated (Table 2C) and without consumable rewards, but with the flashing light contingent on correct responding, the tacters continued to respond correctly to manders' requests by accurately reporting on their internal states 83% to 100% of the time. Tacter 3 pecked a noncorresponding key only once while under amphetamine water deprivation, and Tacter 2 committed the other two errors for this condition. The mean accuracy of the tacters' performance on trials subsequent to the first, for satiated sessions, was: amphetamine, 92%; chlordiazepoxide, 90%; and saline, 90% (see Appendix 3). The overall accuracy of the interanimal correspondence for this condition ranged between 71% and 92% (chance performance would give an accuracy measure of approximately 11%).

ANCILLARY ASSESSMENTS

After completing Phase 3 of this study, key-pecking rate measures were obtained for all three tacters under administration of each of four pharmacological agents as well as saline. These assessments were accomplished without participation of the manders, using the training program that had been employed prior to the interanimal interaction. Three sessions with 30-min presession injection intervals (chlordiazepoxide, saline, *d*-amphetamine) were followed by four sessions with 20-min presession injection intervals (saline, pentobarbital, saline, cocaine). All 7 test days were conducted under food deprivation with the birds at 85% of their free-feeding weights. The amount of time it took the birds to earn 40 reinforcers (from the first correct response to final delivery of the food hopper) was as follows: 3 mg/kg cocaine (382 s), 8 to 12 mg/kg pentobarbital (391 s), 2 mg/kg *d*-amphetamine (431 s), 8 mg/kg chlordiazepoxide (425 s), saline (424 s). These times represent the interanimal mean for each condition; the saline time was computed from data collected on all three saline days (nine data points), and can be viewed as the birds' base rate.

DISCUSSION

Pigeons were conditioned to respond discriminatively to three distinct interoceptive states; they were also trained to communicatively exchange arbitrary discriminative stimuli as a function of these states. Moreover, the tacters' discriminative performances generalized to similar interoceptive stimulus conditions and, ultimately, were observed in the absence of a primary establishing operation and when unconditioned reinforcers were no longer delivered. The pigeons' tendency to interact in this manner was directly related to the adequacy of their experience and the strength of their repertoires for reporting on such private events.

The tacters' behavior involved tacting private events (via a matching-to-sample performance in which the sample stimuli were interoceptive). The birds were conditioned to discriminate three internal states by pecking lettered response keys, and the discrimination was reinforced with a generalized conditioned reinforcer (a stimulus paired with deliveries of food and of water). Further, reinforcement of their discriminative behavior did not covary with the particulars of their state of deprivation or aversive stimulation; their discriminative responses were reinforced under both food and water deprivation conditions and when satiated. The manders, on the other hand, were conditioned to emit impure mands (i.e., verbal responses jointly controlled by a specific state of deprivation (food) and maintained by the deprivation-relevant reinforcer, and by discriminative stimuli provided by the tacters).

One difference between the manner in which our subjects learned to tact private events and Skinner's (1945, 1984) hypothesis of how humans acquire this skill is the schedule of reinforcement during conditioning. In the present study, the private events experienced by our subjects (i.e., the drug states they were conditioned to tact) were controlled with virtually 100% reliability and validity; our subjects' accurate reports on their interoceptive states were reinforced on a continuous reinforcement schedule (CRF). The manner in which humans typically learn to tact private events, according to Skinner, is much less precise, and reinforcement of doing so is intermittent.

The persistence of generalized discriminative responding maintained via the behavior of another organism suggests that the tendency for animals to report on similar, though somewhat different, internal experiences can be taught. Technically, the verbal responses emitted by the tacters during this phase of the experiment qualify as *extended tacts.* "There are several ways in which a novel stimulus may resemble a stimulus previously present when a response was reinforced, and hence there are several types of what may be called 'extended tacts' " (Skinner, 1957, p. 91). To the extent that these results adequately depict the manner in which humans come to report on related but novel feelings, they are consistent with Skinner's (1945, 1984) hypothesis of how humans acquire this skill: Skinner suggests that people are able to describe novel feelings because these states often share features with familiar feelings on which they have learned to report (i.e., extended tacts based on interoceptive stimulus generalization).

Most of the component behavioral units displayed by our subjects have been observed in earlier work but had not been synthesized in this manner to build an animal model of human communicative behavior. Catania (1983) has discussed the utility of such demonstrations: "Behavioral analysis begins with complex behavioral relations and breaks them down into their components. One test of the adequacy of such an analysis is an experimental synthesis (e.g., Catania, 1972; Catania & Keller, 1981).... Sometimes we begin with concepts from human affairs as the bases for producing novel behavioral relations. The synthesis consists of creating within the laboratory a performance in some respects analogous to human behavior outside the laboratory ... once a phenomenon has been demonstrated by a behavioral synthesis, its defining properties and its range of applicability can be refined by subsequent research. The success of a synthesis is then judged not only on the bases of the empirical results but also on the extent to which the refined understanding of the phenomenon has implications for the human nonlaboratory situations from which the analog emerged" (pp. 58–59). (For related discussions, see Lubinski & Thompson, 1986; and Thompson & Lubinski, 1986.) Of the four classes of human behavior enumerated by Epstein (1984) as candidates for animal simulation research, only *covert behavior* (i.e., thoughts, feelings, and images) have resisted empirical analysis using animal simulations. The present study demonstrates that this class of behavior is also amenable to objective analysis via simulation with nonhuman subjects.

The present findings suggest that interoceptive stimuli and novel events at the neuroreceptor level not only are discriminated but can come to be reported to other organisms. Nonhuman organisms can be taught to make such discriminations and report them to their neighbors, communicatively, through a learning process, and will continue to do so even without a primary establishing operation and unconditioned reinforcement. At the same time, it is unlikely that the performances studied here constitute linguistic activity as the term is usually understood (Brown, 1970). There is no reason to suppose any syntactic structure is inherent in the pigeons' response sequences nor any reason to impart complex intentionality to the birds' communicative exchanges. Nonetheless, the character of the perfomances share features with those seen in very young children or severely handicapped youth (e.g., children with autism) who are just beginning to respond differentially to and report on their own internal feelings (Lovaas, 1981). They require a social community to begin to learn how to report on their internal states, but their self-reports often seem rigid and restricted to a very narrow realm of available learning experiences.

Savage-Rumbaugh (1984) has pointed out differences between the behavior of the chimpanzees involved in her research and the pigeons in the Epstein et al. (1980) study, which she believes cast doubt on the claim that the birds in the latter investigation were actually engaged in communicative activity. The pigeons, Savage-Rumbaugh (1984) argues, were not trained in a verbal environment, hence could not properly be said to be engaged in verbal behavior. Moreover, she claims that since the contingencies brought to bear on the pigeons' behavior were imposed by electronic circuitry rather than by another individual, the result could not reasonably be characterized as "communication." The same concerns would presumably be applicable in the present investigation, because the birds were not trained by people who communicated like pigeons or pigeons who communicated like people, nor were the exchanges of discriminative stimuli mediated without the assistance of electronic circuitry. The pigeons' experimental verbal community (i.e., the other independently trained pigeons) was restricted to an extremely limited range of behavior conforming to the functional form of a dyadic exchange of cues. Thus, the question is, "Given a conspecific audience prepared to respond discriminatively to a very limited range of verbal cues, would a pigeon given the opportunity to report on its internal environment do so, without being hungry or thirsty, or being fed or given water for so doing?" The answer seems to be "Yes."

We believe the role of external circuitry in mediating the exchange is less germane to the question at hand. There are countless examples of human dyadic exchanges in which portions of the contingencies between participants' stimuli and responses are mediated by external events between the speaker and the listener over which they have no control, and we are still content to refer to such exchanges as "verbal." These contingency manipulations range from poor telephone connections between speaker and listener to messages left on computer bulletin boards that may be responded to by a computer rather than by a person. The essential question has to do with the functional relations between speaker and listener and the controlling variables, not how the variables get implemented.

If we have correctly described key features of the way in which humans typically learn to report on internal milieus, we may be in a better position to begin to understand individual differences in people's ability to adequately report on internal events. In the present experiment, the pigeons' ability to report on their internal states depended on the adequacy of their experiences (specifically, discriminative training as a function of internal events manipulated pharmacologically). If the same holds for people, one might expect large individual differences in ability to report internal feelings depending on the adequacy of their discriminative learning histories with respect to interoceptive events, often acquired under the tutelage of parents (or in some instances later in life, e.g., via counseling or psychotherapy). In addition, if one assumes there are substantial constitutional and/or genetically determined individual differences in the availability of types of receptors upon which neurotransmitters can act (with their correlated affective events), we would expect significant individual differences in competence for reporting internal experiences.

The notion that specific internal stimulus events are critical components of emotion has been widely held since William James (1890), and recent evidence and theoretical suggestions concerning the relation of the benzodiazepine-GABA receptor complex to human anxiety lends credence to this idea (Gray, 1982; Poshivalov, 1987). Evidence from the increasingly refined animal laboratory drug discrimination procedures reveals that animals can report on events at the neuroreceptor level much as organisms are able to respond differentially to the way rod and cone cells in the retina are activated. This suggests that it may be possible to understand more objectively the role of internal affective states by combining the technologies of the animal drug discrimination model with those of receptor chemistry. Further, the interorganism communication of certain qualities of affective states can be assessed by coupling these methods with the domain of interanimal communication. As Skinner (1953) remarked over 30 years ago, "The line between public and private is not fixed. The boundary shifts with every new discovery of a technique for making private events public. . . . The problem of privacy may, therefore, eventually be solved by technical advances" (p. 282).

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APPENDIX 1

Accuracy of the tacters' discriminative responding in trials subsequent to the first matching response of Phase 1, with deprivation conditions collapsed. The first column reports the mean % correct across all sessions, and the second column contains the standard deviation of this percentage.

	Mean % correct	*SD*
Tacter 1		
Cocaine 3 mg/kg ($n = 10$)	99	2.3
Pentobarbital 8 mg/kg ($n = 10$)	98	3.7
Saline ($n = 20$)	98	2.6
Tacter 2		
Cocaine 3 mg/kg ($n = 10$)	95	5
Pentobarbital 8 mg/kg ($n = 10$)	97	4.1
Saline ($n = 20$)	97	5.9
Tacter 3		
Cocaine 3 mg/kg ($n = 10$)	99	2.1
Pentobarbital 12 mg/kg ($n = 10$)	99	2.6
Saline ($n = 20$)	98	6.2

APPENDIX 2

Accuracy of the tacters' discriminative responding in trials subsequent to the first matching response of Phase 2, with deprivations conditions collapsed. The first column reports the mean % correct across all sessions, and the second column contains the standard deviation of this percentage.

	Mean % correct	*SD*
Tacter 1		
Amphetamine 2 mg/kg ($n = 4$)	97	3.6
Chlordiazepoxide 8 mg/kg ($n = 4$)	95	10
Saline ($n = 8$)	99	4
Tacter 2		
Amphetamine 2 mg/kg ($n = 4$)	98	3.6
Chlordiazepoxide 8 mg/kg ($n = 4$)	92	13
Saline ($n = 8$)	97	5
Tacter 3		
Amphetamine 2 mg/kg ($n = 4$)	99	1.3
Chlordiazepoxide 8 mg/kg ($n = 4$)	100	0
Saline ($n = 8$)	99	1.1

APPENDIX 3

Accuracy of the tacters' responses during the satiated sessions of Phase 3 subsequent to the first trial. Each tacter experienced two sessions for each (amphetamine, chlordiazepoxide, and saline) condition. The fractions represent the total number of correct responses divided by the total number of matching responses; the percentages represent the tacter's accuracy for this performance.

Tacter 1	
Amphetamine	
2 mg/kg	4/4 = 100%, 4/4 = 100%
Chlordiazepoxide	
8 mg/kg	4/5 = 80%, 4/4 = 100%
Saline	4/4 = 100%, 4/7 = 57%
Tacter 2	
Amphetamine	
2 mg/kg	4/6 = 67%, 5/5 = 100%
Chlordiazepoxide	
8 mg/kg	4/5 = 80%, 4/4 = 100%
Saline	4/4 = 100%, 4/5 = 80%
Tacter 3	
Amphetamine	
2 mg/kg	4/4 = 100%, 4/5 = 80%
Chlordiazepoxide	
8 mg/kg	4/4 = 100%, 4/5 = 80%
Saline	4/4 = 100%, 4/4 = 100%