THE ABILITY OF RATS TO DISCRIMINATE THEIR OWN BEHAVIOURS*

RICHARD J. BENINGER,† STEPHEN B. KENDALL, AND C.H. VANDERWOLF
University of Western Ontario

ABSTRACT

Rats' ability to discriminate their own behaviour was studied in a four-lever box. A buzzer indicated the availability of a reinforcement on one lever and the correct choice was determined by the rat's own behaviour at buzzer onset. Face-washing, walking, rearing, and immobility were discriminated at a performance level well above chance. These discriminations were probably not based on environmental cues. The similarity of this "self-report" in rats to self-report in man is discussed.

THE ABILITY OF HUMANS to describe their own behaviour or internal states is referred to as "self-awareness" and is sometimes regarded as a uniquely human ability. However, it has been shown that rats can discriminate hunger and thirst (Bolles & Petrinovich, 1954; Hull, 1933; Leeper, 1935) and that dogs and monkeys can discriminate various types of visceral stimulation, using salivation, leg-flexion, or bar-pressing as the indicator responses (Bykov, 1959; Slucki, Adam, & Porter, 1965). These findings suggest that mammals other than humans are "aware" of internal states.

The present research investigated the ability of rats to respond differentially according to their own behaviour. Rats were trained to press one of four levers when a buzzer sounded, the correct response depending on the behaviour in progress at buzzer onset. The behaviours of immobility, face-washing, walking, and rearing were selected since their spontaneous frequency is fairly high. Also the former two behaviours were selected because they are accompanied by large amplitude irregular electrical activity (LIA) of the hippocampus and the latter two because they are accompanied by rhythmical slow electrical activity (RSA) of the hippocampus, suggesting that they belong to distinct functional groups (Vanderwolf, 1971).

METHOD

Subjects

Four experimentally naive male black hooded rats (A, C, D, and E), approximately three months of age, were maintained at 76.5–83.5 per cent of their free-feeding body weights throughout the experiment.

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†Now at McGill University, Montreal, Quebec. Reprints can be obtained from the first author, Department of Psychology, McGill University, Montreal, 101, Quebec.

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Apparatus

The experimental chamber was a semicircular box with a radius of 30.5 cm and a depth of 36.7 cm. The wooden floor was painted with a white sealer; the semicircular wall was made of Arborite and the straight wall was made of galvanized steel. Reinforcement was provided by a small liquid dipper (Lehigh Valley Electronics model number 114-02) located in the middle of the straight wall 3.8 cm above the floor. Manipulanda were 4 levers (Lehigh Valley Electronics model number 121-03) located equidistant from the dipper at 36°, 72°, 108°, and 144° around the semicircular wall at a height of 3.8 cm. Plastic cue-light disks, 1.5 cm in diameter were located 5.2 cm above each lever and 6.4 cm above the dipper. A small electric buzzer, clamped to a retort stand, was located 50.0 cm above the dipper. Finally, a closed circuit television camera was situated vertically above the experimental chamber. BRS-Foringer Electronics solid state switching and timing devices, located in the same room, were used to program the contingencies. Since these devices had no moving parts, they made no sound when operated; any modules which had indicator lights to signal their operation were covered with black tape. The room was provided with constant masking noise.

A closed circuit television monitor, as well as electromechanical counting and timing devices which recorded the number of both correct and incorrect responses and response latencies on each of the 4 levers, were located in an adjacent room from which the experiment was conducted. This arrangement minimized the possibility of inadvertently providing discriminative cues to the rats.

Procedure

The four rats received variable numbers of sessions in the successive phases of training as a result of their different levels of performance. Some details of the training procedures for each rat also differed, in an attempt to develop optimal training procedures. Therefore, the training procedure for rat A will be described in detail and will be followed by a summary of the procedural variations used in training rats C, D, and E. The experimenter controlled all sessions of the experiment while watching the closed circuit television monitor. All behaviours, as described below, were defined according to the given criteria as seen by the experimenter.

Rat A: Before training was begun (pre-training phase), rat A was exposed to the experimental chamber for 3 sessions during which the feeder cup was randomly presented. The lever-press response was then shaped with reinforcement consisting of a 5-sec dipper presentation of 0.1 cc of Nestles' Sweetened Condensed Milk mixed in 1:1 proportion by weight with water. The 4 levers were numbered clockwise and the response was shaped on lever 4. During shaping, the cue-light above lever 4 remained on; once responding occurred, the light was switched off simultaneous with the presentation of the reinforcer and came back on after a short delay. This procedure was used in order to establish the illumination of the cue-light above the lever as a discriminative stimulus for lever pressing, since responses which occurred when the light was not illuminated had no programmed consequences. A session of continuous reinforcement followed shaping. Session length varied from 25 to 60 min during the initial phases of the experiment and the number of reinforcements varied from 25 to 90 per session. These variations were necessitated by the nature of the training; however, both session length and number of reinforcers per session were fairly constant for the last portion of the study (see phase 4 below).

During the next 3 sessions (phase 1) the onset of illumination of the cue-light above lever 4 was paired with the sounding of the buzzer for a 1-sec duration. This operation was termed an *activation* since concurrent with the sounding of the buzzer and the onset of cue-light illumination was the turning on (or activating) of lever 4 which could then be pressed to produce reinforcement. At this point, however, activations of lever 4 did not occur randomly, but rather were only made when the rat was REARING; rearing was defined as a posture in which the rat's weight was supported by the hind legs, the forelegs hanging freely, and the back approximately vertical. Lever 4 will therefore be called "the rearing lever."

During the following 15 sessions (phase 2) activations of lever 3 were randomly interspersed among activations of lever 4. Lever 3 was only activated, however, when the rat was FACE-WASHING; face-washing was defined as high frequency rotatory movements of the forepaws over the face of the rat. To ensure that the response was temporally contiguous with activation, the duration of time during which a lever remained activated was set at approximately 5.0 sec. Also, if a response was made on a lever other than the one activated, the activated lever was immediately turned off and no reinforcement was presented. Over the course of the sessions of phase 2, the amount of illumination of the cue-lights above lever 3 (the face-washing lever) and the rearing lever at activation was systematically decreased until, for the last 4 sessions, the cue-lights were never illuminated. (Remember that the buzzer sounded at activation so that there was still a signal.) Levers 3 and 4 were still activated only when the rat was face-washing or rearing respectively, but no lights were presented to indicate which lever was activated.

During the next 5 sessions (phase 3), activations of lever 2 were randomly interspersed among activations of lever 3 and lever 4. Activations of lever 2 only occurred when the rat was WALKING; walking was defined as a behaviour in which all 4 legs made sequential contact with the floor and in which at least 3 legs moved (3 steps). Phase 3 was begun with the cue-light above lever 2 (the walking lever) fully lit at the time of activation; however, over a series of sessions the light was faded out until, by the end of the phase, there was no cue-light illumination.

Phase 4 consisted of 38 sessions with an average length of 35 minutes and 15 activations of each of levers 2, 3, and 4 presented in a random order per session. The cue-lights were never illuminated during this phase.

Rat C: Training procedures were similar in all phases; however, the number of sessions per phase differed. Phase 2 was carried out over 26 sessions, phase 3 over 13 sessions, and phase 4 over 24 sessions.

Rat D: The pre-training phase and phase 1 followed the procedure described for rat A. However, during phases 2 and 3, the cue-lights were not faded out as they were for rat A. Phase 2 was carried out over 9 sessions and phase 3 was carried out over 6 sessions. Activations of lever 1 were then randomly interspersed among activations of levers 2, 3, and 4. Lever 1 was only activated when the rat was IMMOBILE; immobility was defined as non-movement, including head or body movements, for a perceptible time (about 0.5 sec). The cue-lights above the 4 levers were then all faded out at an equal rate over 32 sessions. Phase 4 consisted of 14 sessions with an average length of 35 minutes and 10 activations of each of levers 1, 2, 3, and 4 presented in a random order per session. As was the case for rats A and C, the cue-lights were never illuminated during phase 4.

Rat E: The training procedures used for rat E were the same as those described for rat D; however, the cue-lights above the 4 levers were faded out over 21 sessions (instead of 32 as for rat D) and phase 4 included 23 sessions.

The recorded number of both correct and incorrect responses and response latencies were transferred to computer data cards. Data analysis was then carried out with the use of the University of Western Ontario Computing Centre.

The entire experiment was carried out in the summer of 1972 and testing had to be discontinued at the start of the fall term. During phases 2 and 3, early in the summer, it became apparent that rats A and C could discriminate among three of their own behaviours (walking, face-washing, and rearing). Therefore the cue-light fading procedures were omitted for rats D and E during phases 2 and 3 and a fourth behaviour (immobility) was added. Training continued and the cue-lights above all four levers were faded out at an equal rate. Because this fading procedure required many sessions (32) for rat D, only 14 days remained available for testing during phase 4.

Results

An activation of a lever may be regarded as a trial with two possible outcomes: (*a*) a correct response which was a response on the activated lever, or (*b*) an incorrect response which was either a response on a lever other than the activated lever or no response. The total number of correct responses (tC) expressed as a ratio of the total number of activations (tA) was designated *Y* and would have a value from 0 to 1.00. *Y* was called the frequency of correct responses per activation and was described by the equation $Y = tC/tA$. The higher the value of *Y*, the more often the rat responded correctly at activation. If a response occurred after each activation and if performance was at a chance level, then for rats A and C, *Y* would be expected to be about 0.33, and for rats D and E, *Y* would be expected to be about 0.25. A random sample of 20 sessions (5 for each rat) taken from phase 4 indicated that a response occurred after 95 per cent of the activations; therefore, the chance levels for performance in this experiment would be only slightly lower than those given above. For this reason, the above chance levels will be used in the discussion of the *Y* ratios.

The frequency of correct responses per activation (*Y*) was calculated for each lever for each rat for all sessions of phase 4. These *Y*-scores are shown in Figure 1. From these *Y* values the *mean* frequency of correct responses per activation for each lever for each rat was calculated. These means and their standard deviations are presented in Table 1. The data showed that for the face-washing lever and the rearing lever for all rats at least 97 per cent of the *Y* values fell above the chance level (only 50 per cent of the values would be expected to fall above chance if random responding were occurring). For rats A and C at least 99 per cent of the *Y* values for the walking lever also fell above the chance level and for rats D and E, at least 80 per cent of the *Y* values for the immobility lever and the walking lever fell above chance. From these data it appeared that the rats could respond correctly at activation of any one of the levers at a performance level well above chance.

As stated above, an activation was a trial which had two possible outcomes: a correct or an incorrect response. The *Y* values were calculated on the basis of the correct responses making no consideration of the locus

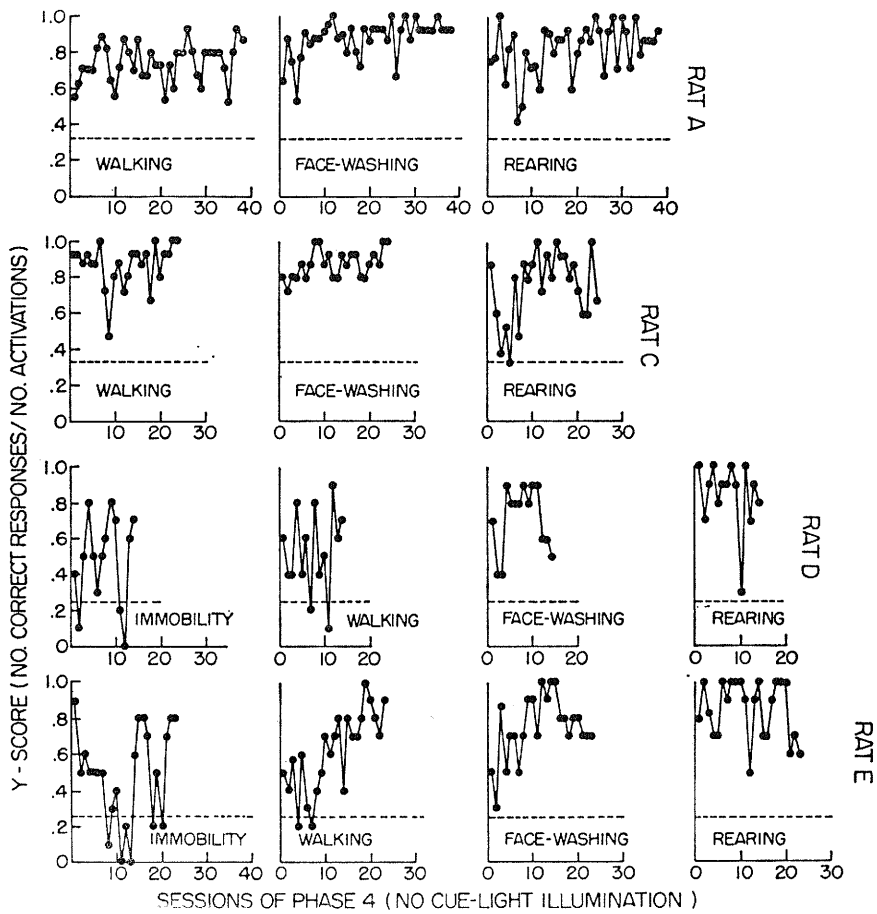

FIGURE 1. The frequency of correct responses per activation (*Y*-scores) for each lever for each rat for all sessions of phase 4. Broken horizontal lines show chance performance levels.

of the incorrect responses. An incorrect response was defined as a response on a lever other than the activated lever or no response. If the responses on a lever other than the activated lever (i.e., errors) were not equally distributed among the other levers, then the chance level for *Y* would be altered. For example, if 3 levers were each activated 5 times and if a rat always pressed the first of the 3 levers at activation, then the *Y* value for that lever would be 1.00. Clearly this *Y* value would not indicate the discrimination performance of this rat. For this reason a second ratio was calculated. For each rat the total number of times an error was made on each lever was recorded. It was therefore possible to express the total

TABLE I

PERFORMANCE LEVEL OF RATS DISCRIMINATING THEIR OWN BEHAVIOURS

Rat	*Y*-score (mean number of correct responses per activation)				*X*-score (mean number of correct responses per response)			
	Levers				Levers			
	Immobility	Walking	Face-washing	Rearing	Immobility	Walking	Face-washing	Rearing
A		0.74 (0.11)*	0.88 (0.10)	0.82 (0.14)		0.86 (0.10)	0.78 (0.11)	0.89 (0.10)
C		0.87 (0.12)	0.88 (0.08)	0.75 (0.19)		0.88 (0.09)	0.84 (0.11)	0.93 (0.08)
D	0.48 (0.25)	0.53 (0.23)	0.71 (0.18)	0.84 (0.19)	0.62 (0.30)	0.65 (0.23)	0.71 (0.15)	0.83 (0.18)
E	0.48 (0.27)	0.62 (0.22)	0.75 (0.18)	0.84 (0.16)	0.69 (0.28)	0.57 (0.14)	0.76 (0.13)	0.81 (0.13)

*Nos. in parentheses are standard deviations.

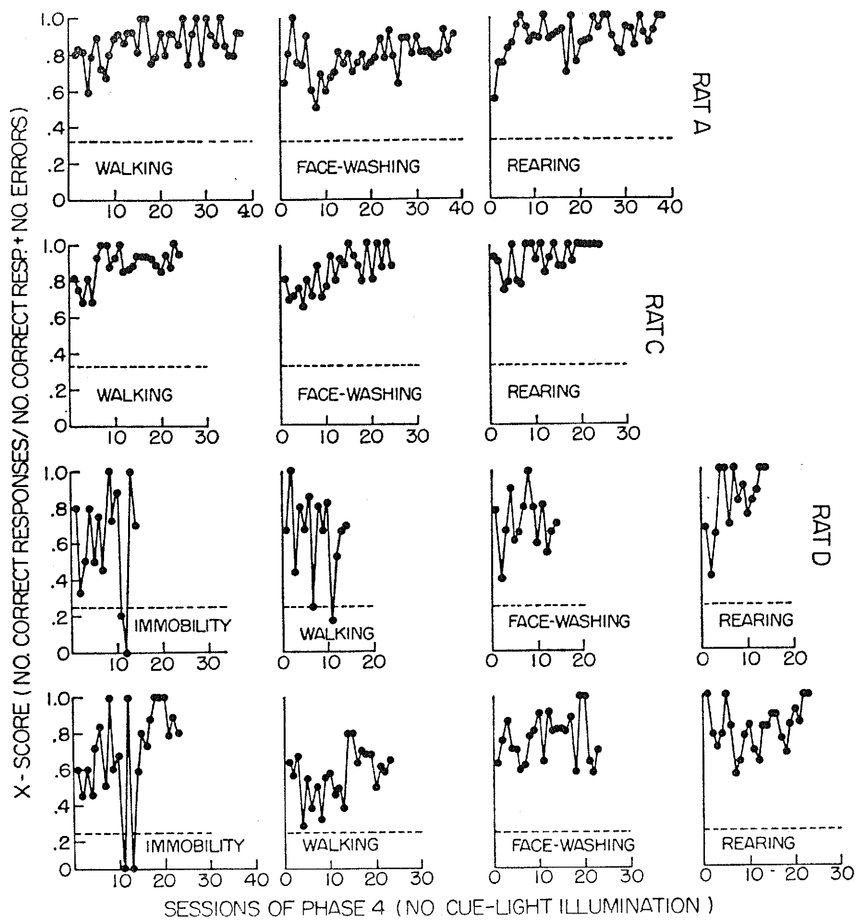

FIGURE 2. The frequency of correct responses per response (*X*-scores) for each lever for each rat for all sessions of phase 4. Broken horizontal lines show chance performance levels.

number of correct responses as a ratio of the total number of correct responses plus the total number of errors (tE) made on a lever. This ratio was designated *X* and would have a value from 0 to 1.00. *X* was called the frequency of correct responses per response and was described by the equation: $X = tC/(tC + tE)$. The closer the ratio to 1.00, the greater the number of responses that occurred on that lever that were correct. *X* would be expected to be about 0.33 for rats A and C and about 0.25 for rats D and E if performance was at a chance level.

The frequencies of correct responses per response (*X*-score) for each lever for each rat for all sessions of phase 4 are shown in Figure 2. The means and standard deviations of these X-scores are shown in Table 1. In every case, at least 89 per cent of the X values fell above the chance performance level. Clearly, when a response occurred it was most often correct.

Where both the Y and the X values were high for a particular lever, it was concluded that not only was the frequency of correct responding at activation high, but also that few errors were made on that lever. Only in the case of responding on the immobility lever for rats D and E, where the Y values were less than one standard deviation above chance, would this conclusion be made with some reservation.

It remained to determine if there were any stimuli in the environment of the experiment which were cueing the differential responding. Since closed circuit television was used, possible biasing effects of the experimenters' presence were removed. It became increasingly clear, however, that the rats were all developing stereotyped behaviour patterns while in the experimental chamber such that they would often perform a particular behaviour in the same location. Rat E, for example, would face-wash in the right hand corner of the box, walk to the left side and rear, turn and walk across in front of the dipper and become immobile for approximately 1.0 sec. Rat E would then return to the corner and begin again to face-wash. For this reason data were collected to determine the location of the rat in the chamber at the sounding of the buzzer at activation. These data were collected for 5 sessions (75 activations per lever) for rats A and C, for 4 sessions (40 activations per lever) for rat D, and for 5 sessions (50 activations per lever) for rat E. At each activation the snout of the rat, including the direction it faced, was located by writing an arrow in a semicircle drawn on a sheet of paper. A grid system (Fig. 3), which divided

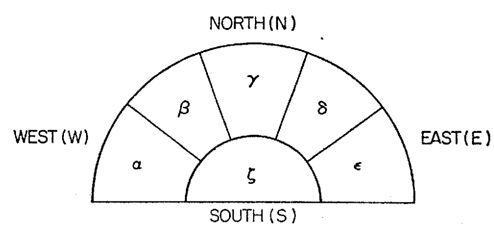

FIGURE 3. Illustration of the grid system and directions used to locate rats at activation.

the chamber into 6 equal area portions was then superimposed on the semicircles making it possible to determine in which of the 6 areas (α, β, γ, δ, ϵ, ζ) and in which direction (N, E, S, W) the rat was facing when each activation occurred. (The word location will be used to refer

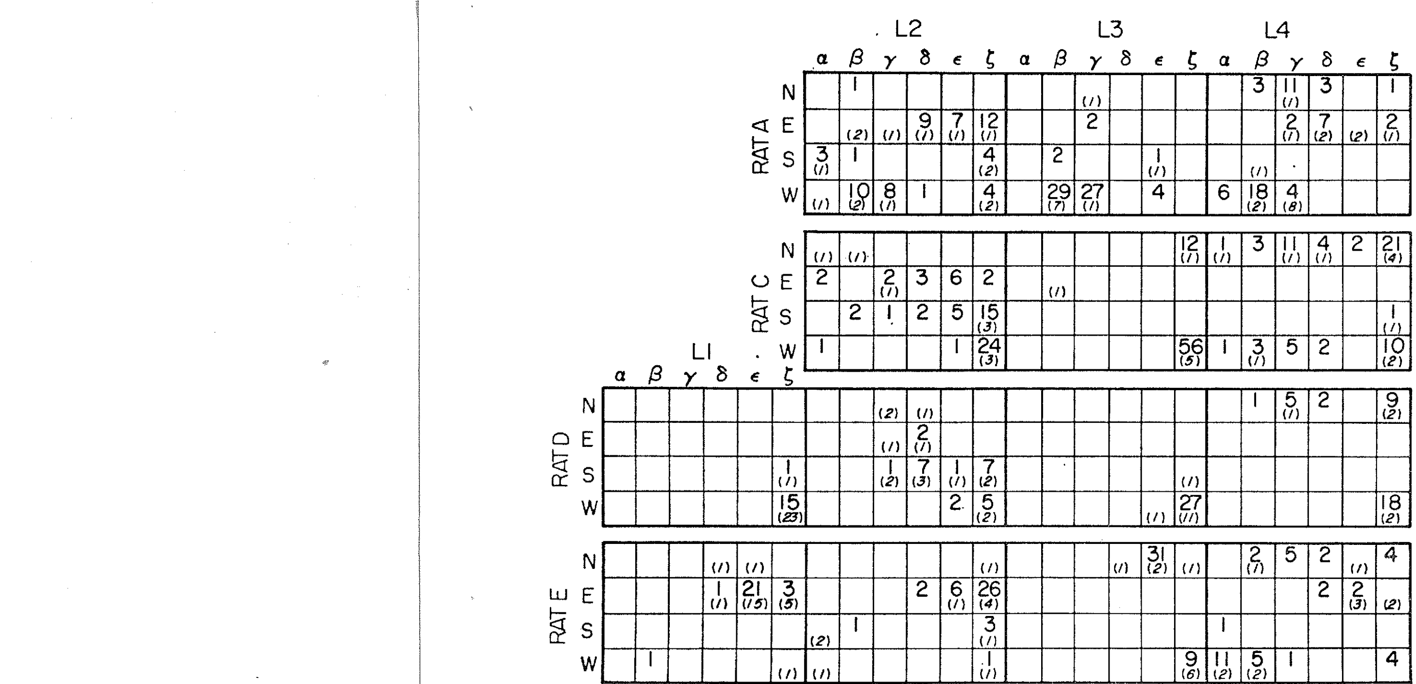

FIGURE 4. The location of each rat at lever activation during 4–5 sessions (see text). Gothic numbers represent the number of times that a correct response occurred at activation; italicized numbers represent the number of times that an incorrect response occurred at activation. The Greek letters represent areas of the chamber, and direction is indicated by the letters N, E, S, and W. Behaviours associated with levers are L1, immobility; L2, walking; L3, face-washing; and L4, rearing.

to any area-direction combination.) The location data are presented in Fig. 4.

There were two basic tests which were made from the data. The first test was to determine if a particular response on a lever at activation could be made successfully from different areas and/or directions in the chamber. This was clearly the case for rat A which responded accurately on the rearing lever (lever 4) from βN, γN, αW, βW, δE etc. Responses of rat A on the face-washing lever (lever 3) however, proved to be almost entirely restricted to βW and γW, both the same direction in two adjacent areas. Therefore, the second test was used which determined if other behaviours also occurred in the same area and direction. For rat A, the data again supported the notion that the rats' location at the time the behaviour was performed was not acting as the discriminative stimulus; responses on the walking, the face-washing, and the rearing levers were all made accurately from βW.

TABLE II

THE MEAN LATENCY (SEC) OF LEVER-PRESS RESPONSES OF RATS DISCRIMINATING THEIR OWN BEHAVIOUR

Rat	No. sessions	Levers			
		Immobility	Walking	Face-washing	Rearing
A	38		1.39 (0.44)*	1.61 (0.32)	1.39 (0.24)
C	24		1.91 (0.41)	2.24 (0.35)	1.45 (0.44)
D	14	2.72 (0.84)	2.47 (0.64)	2.19 (0.88)	1.64 (0.65)
E	23	2.20 (1.38)	1.30 (0.73)	1.53 (0.53)	1.27 (0.34)

*Nos. in parentheses are standard deviations.

An overview of the data indicated that for rats A, C, and D, for all behaviours except immobility, the conditions for one or both of these tests were fulfilled. With immobility (lever 1) rat D showed a strong tendency always to perform the behaviour in the same location but performance was not very much better than chance although rat D did respond accurately on other levers from the same location. For rat E there was some evidence that face-washing (lever 3) and immobility (lever 1) were not being performed on the basis of location alone but more data would be needed before any conclusions could be drawn.

Data on latency of response to different levers were also examined. Response latency was defined as the time between the onset of activation (i.e., the sounding of the buzzer) and the occurrence of a correct response. The latency times were accumulated for each lever over a session. If an incorrect response occurred, the latency of that incorrect response was subtracted from the total latency. The total latency was then divided by the number of correct responses plus the number of omissions in order to get a measure of response latency. An omission was defined as no response occurring, correct or incorrect, during the activation time. As stated earlier, each lever remained activated for only 5.0 sec; therefore, an omission would be recorded as a response with a latency of this duration. The mean response latencies during phase 4 for all rats are presented in Table II. The most striking consistency in the data was that the latency on the face-washing lever was longer than the latency on the walking lever and the rearing lever for rats A, C, and E; for rat D the latency on the face-washing lever was longer than the latency on the rearing lever but not longer than the latency on the walking lever. The latencies on the immobility lever, although highly variable, were longer than the latencies for all other levers for rats D and E. The longer latency measured for lever-presses which followed face-washing might be explained by the nature of the behaviour. It was observed that on many occasions when the buzzer sounded at activation during face-washing, the rat would continue to face-wash (i.e., making high frequency rotatory movements of the forepaws over the face) as if completing a predetermined sequence, before the lever-press was made. It happened, although rarely, that the rat would continue face-washing for the full duration of the activation time (5.0 sec) and fail to respond at all. Similar delays in responding were not observed when buzzer activation occurred during walking and rearing. These observations may account for the longer latencies on the face-washing lever.

One other trend was seen in these data when changes over days were examined. For both rats A and E, the latencies, especially those for the face-washing lever for rat A and those for the immobility and the face-washing levers for rat E decreased over the sessions of phase 4. For both A and E, these latencies actually became shorter than those for the rearing lever by the end of the training. Decreasing latencies on the face-washing lever for rat C indicated that rat C may also have been showing this trend by the end of training. Latency data for rat D indicated no similar trend, probably because rat D received only 14 sessions during phase 4.

No specific data were collected to determine the frequency of the 4 behaviours before training was begun. It was apparent, however, that the activity level of the rats in the experimental chamber increased over the course of the early phases and that the frequencies of the 4 behaviours increased. For example, it was noted that rat A face-washed 6 times during the first session (25 min) of training to respond to lever 3 at activation but that during the following session (50 min) rat A face-washed 28 times – clearly an increase in frequency. It was interesting to note, however, that on many of the 28 occasions rat A appeared to be "mimicking" the behaviour of face-washing since rat A would pause in the course of the behaviour and sometimes proceed to perform some other behaviour.

Discussion

On the basis of the results it can be asserted with some confidence that a rat can discriminate 3 and possibly 4 of its own behaviours. The question remains as to how a rat is capable of making this discrimination. The data discounted the possibility that the rats were responding differentially on the basis of their location in the chamber. One other possibility would be that different fields of visual stimuli were produced by the different behaviours since, when rearing, the rat's visual field is different than it is when walking; however, the visual field should be about the same for walking, face-washing, and immobility. This suggests that the behaviours were not discriminated on the basis of fields of visual stimuli. Another possibility is that the discrimination was based on proprioceptive or cutaneous feedback.

It should be noted that humans make similar discriminations for which the discriminative stimuli cannot be clearly defined. For example, if someone says "I am walking" or "I am immobile," it is not clear how the discrimination is made. In both cases one may assume as did Mechner (1958) in interpreting the results of his experiments using a "counting" procedure, that some hypothetical response-produced stimuli were acting as discriminative stimuli for the obtained behaviours. Alternatively, it is conceivable that the output of an efferent program for walking, for example, could exert a direct control over a subsequent discrimination response, without the necessity of a loop to the periphery (i.e., "corollary discharge," Teuber, 1960).

The abilities of rats to discriminate several of their own behaviours by responding differentially on a number of levers appears to resemble the verbal discriminations of their own behaviours made by humans. A further development of the technique used to train these rats could lead to improved understanding of "subjective" aspects of the behaviour of animals previously thought to be accessible only in man.

It is interesting that the rats often completed an ongoing bout of face-washing before responding to the buzzer that signalled the availability of reinforcement, suggesting that the sequence of face-washing movements can be interrupted only with difficulty once they have been initiated. Walking and rearing, on the other hand, were stopped immediately when the buzzer sounded. Face-washing behaviour is not readily changed by abnormal experience as shown by Fentress (1973) who found that the movements develop normally in mice in which one or both forelimbs had been amputated above the elbow early in life. Further, unlike walking and rearing, face-washing is not accompanied by activation of the hippocampus (Vanderwolf, 1971). Possibly, the behaviour is essentially automatic or reflexive and is not directly controlled by the cerebral hemispheres.

Résumé

Etude de l'aptitude du rat à répondre différentiellement à son propre comportement dans une boîte à quatre leviers. L'accessibilité au renforcement lié à un levier donné est signalée par un trembleur et le choix exact est déterminé par le propre comportement du rat quand le trembleur commence à résonner. Les résultats montrent que l'animal peut ainsi distinguer beaucoup mieux qu'au hasard des activités telles que de se nettoyer le museau, marcher, se dresser, ou rester immobile, et que ces réponses différentielles ne sont probablement pas basées sur des indices fournis par le milieu environnant. La discussion souligne la ressemblance qui rapproche la "description de soi" par le rat de la "description de soi" par l'homme.

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