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WATER RETRIEVAL BY NORWAY RATS: BEHAVIOR AS DEDUCTION

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ABSTRACT: The origin of behavior consistent with effective ("optimal") policies is an important topic in behavioral biology. In many cases, novel behavior patterns that emerge in unfamiliar situations are based on "trial and error" learning guided by rewards and punishments. The present work shows how an appropriate novel response can emerge full-blown in response to new contingencies if the situation has generic features that can be recognized. This work is concerned with object retrieval, i.e., carriage of valued objects to a place of safety by Norway rats (*Rattus norvegicus* (Berkenhout); Rodentia: Muridae). Experiment 1 shows that selective retrieval of objects containing water over dry objects of the same material can occur immediately when rats are made thirsty; it is unlikely that this is a specific adaptation, since the opportunity to retrieve water in this way would rarely arise under natural conditions. Experiment 2 shows that without initial exposure to both objects under *ad lib* conditions (where the retrieval preference was for the dry objects), a process of trial and error is apparent as thirsty rats learn to select the appropriate object. It is argued that if object retrieval behavior is linked to a generic incentive feature and features such as wetness are recoded into this general term, then appropriate object retrieval can be generated by a kind of deductive process. This type of generalist strategy would appear to be highly adaptive, in part because the usual tradeoffs between specialist and generalist strategies may not apply.

INTRODUCTION

According to behavioral optimization theory, much behavior consists of procedures for implementing policies that optimize quantities critical to Darwinian fitness. This formulation leaves open the means by which an animal comes to act in accordance with an optimal policy. For higher organisms, the procedures need not be pre-programmed; instead these animals can learn to respond in a manner that approaches optimality through feedback in the form of rewards and punishments. Learning of this sort often involves a degree of blind

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search, as reflected in the term "trial and error" (*cf.* the careful early descriptions of instrumental learning in Thorndike [1898] and Small [1900]). This would seem necessary insofar as the animal is dealing with aspects of the environment that are uncertain (*cf.* Plotkin & Odling-Smee, 1979; Johnston, 1982; Shettleworth, 1984).

On the other hand, if the defining features of a common situation can be recognized, it may be possible to generate new procedures by a kind of deductive process. In this case, recognizing a new situation in terms of its generic features may allow a novel but appropriate behavior pattern to emerge at the first opportunity. Possible examples of this are found in the object retrieval behavior of Norway rats and other rodents.

In its general form, this behavior is relatively straightforward. The animal leaves a place of safety and, on encounter with an object of some value which is also transportable, it carries the object back to the safe spot before 'consumming' it. This includes the case in which the animal has already discovered objects in a particular location and directs its activities, including the approach to the objects, toward carrying them to safety. In this case, the rodent appears to implement a policy that involves both maximizing consumption (either at present or at a later time) and minimizing risk of predation (Lima *et al.*, 1985).

Norway rats and other rodents appear to retrieve objects for various purposes, since there are several properties of objects that induce retrieval when the animal is in the appropriate motivational state, and these properties are associated with different motivational systems (Wallace, 1979, 1985). For example, hungry Norway rats will retrieve large numbers of food objects (Morgan *et al.*, 1943), while rats of this species that are well-nourished and not inclined to retrieve food will retrieve objects that they can take apart by gnawing or tearing, which may be related to nest building or to discovering novel foodstuff (Tigner & Wallace, 1972; Wallace, 1994).

In line with this general rule, Bindra (1947) showed that domestic Norway rats when deprived of water would retrieve cotton dental rolls, or pledgets, soaked in water. He noted that it was unlikely that the opportunity to retrieve water occurred often enough during the evolutionary history of these animals for this to be a specific adaptation. They were therefore able to respond appropriately on the basis of their experience in the immediate situation. Bindra found that these pledgets were retrieved on the first trial of testing, perhaps too quickly to have been the product of trial and error learning. However, details of acquisition are unclear, and in addition the effects of novelty were not controlled.

Water retrieval may, therefore, serve as an effective demonstration that retrieval behavior can occur in an appropriate form in a situation that rats would not normally encounter. This paper presents data pertaining to the question of whether water retrieval does, in fact, emerge full-blown, without a period of trial and error. Experiment 1 confirms Bindra's finding using better controls, and includes observations of behavior during the very first opportunity to retrieve following water deprivation.

In this experiment, rats were presented with dental pledgets that were either dry or soaked in water. Following exposure to these objects under conditions of *ad lib* feeding and drinking, the rats were deprived of water and then exposed to the same objects under this condition. A shift to 'water retrieval' that was sufficiently marked and complete would indicate that these animals can in some sense deduce the correct behavior without a period of trial and error with guidance based on feedback from rewards. (As the General Discussion will show, the concept of deduction referred to here does not imply elaborate information processing that might be called "cognitive".)

It might be thought that a more direct test would be to deprive rats of water and, under these conditions, expose them to either wet pledgets alone or to wet and dry pledgets for the first time. However, the results of this test (particularly, the first reponse on encounter with the objects) would be confounded by novelty effects. Domestic rats retrieve on the basis of novelty, i.e., they pick up and retrieve any small object they have not encountered before, and this effect is strong enough to compete with retrieval based on other object features even under stringent deprivation (Wallace, 1979). However, since it is of interest to compare the behavior of rats that encounter these objects for the first time when they are thirsty, a second experiment was run to test this condition.

EXPERIMENT 1

METHODS

Subjects and Apparatus

Twelve Norway rats of the Sprague-Dawley strain were obtained from Simonsen Laboratories, Gilroy, CA. They were housed individually after arrival, given food and water *ad lib*, and handled daily. They were about 70 days old at the beginning of the experiment. In an initial 30-min emergence test, only two rats emerged; these rats can, therefore, be considered "shy". Bindra (1948) showed that timidity measured in this way is highly correlated with amount of retrieval. Four rats were dropped after the first five familiarization trials because they would not emerge from their cages. This left eight subjects, but since this experiment uses a within-subjects design, this was sufficient to obtain statistically reliable results.

The apparatus for each animal consisted of its home cage and a wooden alley placed in front of the open cage during a trial, so the rat could run freely between the two. Cages were 25 x 20 x 20 cm. Cage racks were shielded from light on the top and sides and did not move during the experiment. Alleys were 61 x 20 x 20 cm, open at one end, painted light blue inside (reflectance = 0.9) and covered on top with hardware cloth. Each alley had a bin at the end away from the cage, 20 x 5 x 4.5 cm, divided by a wooden partition into two 10-cm compartments. A piece of plexiglas at the bottom of each half-bin insured that dry pledgets were not dampened by seepage from the other compartment. A separate alley was used for each rat. The average illuminance at the alley surface was 40 lux; the illuminance at the cage floor 2.5 cm from the back was always < 10 lux. During the experiment the temperature was 20-23° C.

Retrieval objects were cotton dental rolls, or pledgets, 1.9 cm in length and 0.6 cm in diameter. The original pledgets, purchased from the Patterson Dental Co., Eugene, OR, were cut in half. Half the pledgets were soaked in tap water; the other half were dry. Wet pledgets weighed about 1.7 g, dry 0.2 g. Water for soaking was kept overnight, so its temperature was similar to water in the rats' water bottles. Forty objects of each type were placed in a bin for each retrieval trial, with wet and dry pledgets in separate compartments. For each rat, placement of wet and dry pledgets in left and right bin compartments during retrieval trials was determined by a different Gellerman order. New pledgets were used for each trial and were removed from the cage immediately after each individual trial.

Procedure

Individual daily trials were given at the end of the light part of a 12:12 LD cycle with darkfall at 10 PM. All trials lasted 10 min. Rats were first given a series of familiarization trials with no objects in the bins, until all rats were entering their alleys within 30 s of the beginning of the trial. Because of the timidity of these rats, the first eight familiarization trials after the initial emergence test were run with lower illumination (< 10 lux in the alleys), followed by four trials with the original illumination.

Retrieval trials began on the day after the last familiarization trial. On each retrieval trial, the number of objects carried to the cage was recorded. On some trials behavioral observations were recorded on score sheets.

The first six retrieval trials were given under *ad lib* conditions. Water deprivation began 24 h after the sixth trial, and the first trial under this condition was given on the following day. During this period, rats were allowed to drink from their water bottles once a day for 10 min. Eight trials were given under these conditions: on Trials 1-5 and 8 rats were allowed to drink from their water bottles immediately after their retrieval trials; on Trials 6-7 they drank before. *Ad lib* drinking was reinstated immediately after the last deprivation trial, and post-deprivation trials began on the next day. Two sets of seven trials were given during the post-deprivation *ad lib* period, separated by five days of rest.

Average water intake for the five days immediately before deprivation was 28 ml for the dark period and 10 ml for the light; during deprivation it was 10 ml (post-trial); during 22 days following deprivation it was 31 ml (dark) and 12 ml (light).

RESULTS

During the first *ad lib* condition, rats retrieved both types of object but showed a definite preference for dry pledgets (Figure 1). Observations of rats before deprivation indicated that less than half the animals retrieved water-soaked pledgets on the first alley entry for a trial, including Trial 1.

After rats were deprived of water, the change in preference was immediate and complete. During the first 5 days of deprivation only two rats retrieved any dry pledgets (≤ 2 on one or two trials). Observations on Trial 1 of deprivation showed that the preference for water-soaked pledgets was evident on the first entry into the alley: on this entry all eight rats picked up and retrieved a water- soaked object. Half the rats first went to the compartment with dry pledgets and contacted these objects, and one first contacted the wet and then the dry pledgets; each of these rats then moved to the side with the wet objects, and immediately picked up a pledget and retrieved it. One animal of the former group did pick up a dry pledget on the initial contact, but after chewing it briefly, it dropped this pledget and moved to the side of the bin with the wet objects. The remaining rats contacted the wet objects on their first encounter, and picked up and retrieved one immediately.

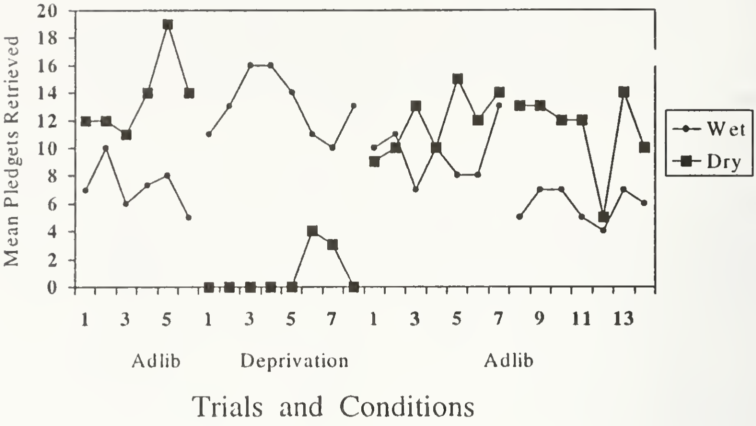

Figure 1. Number of wet and dry pledgets retrieved under *ad lib* drinking and water deprivation (subject-means for each trial). Between Trials 7 and 8 of the second *ad lib* condition there was a five-day break.

On the two days on which water was given before the trial, there was a small but consistent increase in the number of dry pledgets retrieved. In the *ad lib* condition following deprivation, there was an immediate increase in the number of dry pledgets retrieved, but only a slight decrease in retrieval of wet pledgets. During a second post-deprivation series (after a five-day break), retrieval of wet pledgets decreased further, so that the difference was similar to the *ad lib* condition before deprivation. (Bindra [1947] observed a similar slow decline in water pledget retrieval when *ad lib* conditions were reinstated after deprivation.)

Wilcoxon Matched-Pairs Signed-Ranks tests (2-tailed) were carried out to compare objects under each condition. For the first *ad lib* condition, T(8) = 4 (p = .05); for deprivation with water given after, T(8) = 0 (p = .01), and before, T(8) = 4 (p = .05); for successive sets of post-deprivation *ad lib* trials T(8) = 17 (ns) and T(8) = 9 (ns), respectively. In addition, there were statistically significant ($p \leq .05$) differences between conditions: for both objects, between the first *ad lib* condition and deprivation (water after); for dry pledgets, between water after and water before; for dry pledgets, between deprivation and the following *ad lib* condition.

Observations during the trials showed that under deprivation, retrieval of a wet pledget was always followed by oral consummatory behavior (licking, with some chewing and tearing), although in some instances the time spent in this activity was very short. During *ad lib*, neither the wet nor the dry pledgets were necessarily the object of oral consummatory behavior after retrieval. On all trials, a number of pledgets were torn apart to some degree, including both wet and dry pledgets during *ad lib*.

DISCUSSION

The present experiment confirms Bindra's (1947) findings: when deprived of water, Norway rats retrieve objects containing water in preference to other objects. The present work shows, further, that under deprivation water retrieval is immediate and consistent, at least when the rats are familiar with the objects; there is no apparent trial and error even during the very first instance of retrieval. It should be emphasized that these results were found for all rats without exception. This suggests that selective retrieval of an object containing water under conditions of thirst is well within the capacity of most rats of this species.

Preference for the dry pledgets in the first *ad lib* condition is probably related to the greater "partibility" of these objects (*cf.* Wallace, 1994), since dry pledgets were pulled apart to a greater extent than wet ones. It is unlikely that it was due to the greater weight of the wet pledgets, since rats can carry much heavier objects (like food pellets) with ease.

This experiment is a demonstration of "latent learning" of the type in which an irrelevant incentive is presented together with a relevant one during the initial training (e.g. see Rashotte, 1979). Viewed in this context, it is a remarkably robust example of such learning, in comparison with results of classical experiments of this type. The latter include cases where no positive result was found or where the results, while statistically significant, were typically small. The difference may be due in part to the fact that, in the present experiment, rats were not initially in a state of deprivation, since there is evidence that this impairs learning of irrelevant incentives (Meehl & MacCorquodale 1948; Rollin 1958). But even in this case, earlier results were not as marked or reliable. A possible explanation of this difference is that the present paradigm fits the response organization of these animals better than the original latent learning situations did, since it is based on a relation between an object property and a species-typical behavior associated with transportable objects.

EXPERIMENT 2

This experiment was designed to observe patterns of responding when rats encounter the wet and dry objects for the first time under water deprivation.

METHODS

Subjects and Apparatus

Ten male Norway rats of the Sprague-Dawley strain were obtained from Charles River Laboratories, Wilmington, MA. They were kept in pairs in plastic tubs after arrival (at 51 days) and transferred to individual cages one week before testing. They were 83 days old on the first retrieval trial of the experiment. Since only two rats emerged within 30 min on an initial emergence test, these rats can be considered "shy". Two rats were dropped during familiarization trials because they would not emerge from their cages.

The apparatus was similar to that of Experiment 1. Cages were stainless steel, 20 x 24 x 19 cm, with solid backs and sides. Alleys were plywood, 18 x 61 x 18 cm, painted light gray (reflectance = .45). At the end of each alley was a bin 18 x 2 cm, divided in half to form compartments each 8.5 cm wide. Average illuminance under regular lighting at the alley surface was 155 lux, at the cage entrance 117 lux, cage back 8 lux. Under dim lighting it was ≤ 5 lux in the alleys. During the time that the rats were tested the temperature was 21-24° C.

Retrieval objects were cotton dental pledgets, 3.8 cm in length, 0.8 cm in diameter (Roeko dental rolls, Size 1). Dry pledgets weighed 0.4 g, wet pledgets 1.9 g. Twenty-five objects of each type were placed in each bin on each trial. Objects were placed in left and right compartments according to four orders (two rats per order) for the four retrieval trials; in terms of placement of wet pledgets these were, RLRL, LRLR, RLLR, and LRRL. As in Experiment 1, new pledgets were used for each rat on each trial.

Procedure

Individual trials were given daily at the end of the light part of a 12:12 LD cycle with darkness commencing at 8 pm. After the initial emergence trial under regular lighting, rats were given four familiarization trials under dim (red) light, then three such trials under regular lighting. These were 10 min unless the latency to emerge was over one min; in the latter case 10 min were given following emergence. Rats were deprived of water after the first familiarization trial under regular lighting; thereafter, each rat was given 10 min to drink following its daily trial. Four retrieval trials were given beginning on the day after the last familiarization trial. Retrieval trials were 10 min except for one rat on Trial 1 that emerged after 12 min and was given a 20-min trial on that day. On the last familiarization trial and all retrieval trials, behavioral observations were recorded on score sheets.

Average water intake per day for five days immediately before deprivation was 33 ml; during deprivation it was 12 ml (post-trial). It was 60 ml on the day following deprivation and averaged 42 ml on the subsequent eight days.

RESULTS

For all rats, a preference for the wet pledgets developed quickly during the first retrieval trial. Means (per rat) for objects retrieved on successive trials were 11.5, 17.8, 15.8 and 14.4 for wet pledgets, and 2.4, 0.9, 0.3 and 0.3 for dry. Differences in number of objects retrieved on a trial were evaluated with Wilcoxon tests, giving $T(8) = 0$ ($p = 0.01$) for each trial.

On the first retrieval trial, six of the eight rats retrieved a wet pledget initially; in five cases this was on the first entry into the alley. In only two cases was subsequent retrieval restricted to the wet objects. In two cases, rats retrieved several dry pledgets in succession after retrieving (and 'consuming', i.e. licking and chewing) one or two wet pledgets; these rats then switched to wet pledgets for the rest of the trial. Only one rat retrieved wet pledgets exclusively on this trial (although this rat did retrieve a dry pledget on Trials 3 and 4).

On Trial 2, four rats retrieved wet pledgets exclusively, and this number increased to six on Trials 3 and 4. In all but one case, retrieval of dry pledgets on later trials was restricted to single instances in a trial; the exception was a sequence of four retrievals at the beginning of Trial 2.

A partial assessment of the development of this preference was obtained by considering the proportion of rats that picked up an object given that they had contacted it with the snout. This measure has been termed "object seizure: contact" and has been shown to characterize a critical decision in the behavioral sequence underlying object retrieval (*cf.* Wallace, 1997). However, object seizure is not always followed by retrieval, since decision making is distributed in the behavior sequence (*ibid*). In the present analysis, object seizures were tallied for successive contacts during Trial 1, giving the proportion of those rats that picked up an object on the ith contact. These results, along with the number of rats making an ith contact during this trial, indicate that the tendency to respond on contact in this way was roughly equal for both objects at the beginning of the trial. Subsequently, this tendency increased for the wet objects, while it remained at the same level for the dry objects across several contacts and eventually declined to zero (Table 1). On subsequent trials this tendency was nil in most cases for dry objects even on the first contact. In contrast, in the first deprivation trial of Experiment 1, the proportion of seizure responses for dry pledgets was 0.13 for the first contact and zero thereafter.

Table 1. Proportion of Rats Seizing Object on Successive Contacts on Trial 1 of Experiment 2. Wet, Wet Pledgets; Dry, Dry Pledgets; n, number of rats; S:C, Seizure to Contact Ratio.

	Contact Number										
	1	2	3	4	5	6	7	8	9	10	11
Wet											
n	8	8	8	8	8	8	8	8	8	8	8
S:C	0.8	0.8	0.8	1	1	1	0.9	1	1	1	1
Dry											
n	8	8	8	7	6	3	3	3	2	1	1
S:C	0.6	0.6	0.6	0.9	0.5	0.7	0.7	0	0	0	0

DISCUSSION

Although rats quickly developed a nearly exclusive preference for wet over dry objects in this experiment, the preference was not immediate, as it was in Experiment 1 under similar conditions. Clearly, the rats had to learn to do something in this experiment that they could do at the beginning of the first deprivation trial in Experiment 1. This shows that experience with the objects under *ad lib* conditions in the first experiment was critical for the capacity to respond appropriately under conditions of water deprivation at the first opportunity, i.e. to substitute 'deduction' for trial and error learning in establishing an exclusive preference for the wet objects.

As in earlier work (Wallace, 1997), learning in this experiment had two aspects. The rats learned to approach the side with the wet objects (reflected in the decline in number of rats making an i^{th} contact with dry objects). They also learned to inhibit retrieval responses occurring after approach to the objects (here, the object seizure response). However, these tendencies by themselves cannot explain the immediate shift in responding under deprivation in Experiment 1, because during the first *ad lib* condition of that experiment the rats tended to approach the dry objects and inhibit responses to the wet ones.

GENERAL DISCUSSION

Bindra (1947) has argued that it is unlikely that water retrieval is a specific adaptation to thirst, since opportunities to retrieve water probably do not occur often enough in the natural state to allow this behavior to be selected. In support of this, it may be noted that, while there are now a number of field studies of this species, none of them include observations of such behavior. At the same time, rats of this species seem to prefer riparian habitats, and they drink readily from water sources (Lore & Flannelly, 1978; Pisano & Storer, 1948; Telle, 1966). Of course, rats will usually obtain water as well as other nutrients from the foodstuff they retrieve, but water itself is probably not important for food retrieval, as shown by the proclivity of hungry Norway rats to hoard dry food pellets. It is significant that in both Bindra's original study and the present work, water was contained in an object that is itself inedible (and which rats showed no signs of ingesting, even while extracting water from it). This sets the problem in high relief, because in this case object retrieval is based on water without reference to any other nutrient. (And there is no question of the rats retrieving cotton rolls because of stimulus generalization or confusion with some nutrient, since under these conditions there was absolutely no retreival of the same pledgets if they were dry.)

It might be argued that after detecting the wetness of a pledget, a rat would naturally pick it up in order to lick it, and this act of grasping an object while outside a home or refuge provides the stimulus for object carrying. But, in the first place, it is not clear that water detection would be 'naturally' linked to anything but licking. Yet on the first encounter with the objects on Trial 1 of deprivation in Experiment 1, no rat licked the wet pledgets before picking one up, and half the rats simply picked one up and carried it to the cage without any licking in the alley. (The remaining rats licked the pledget briefly after seizure before carrying it to the cage.) Secondly, object seizure does not automatically lead to carrying. Rats can make the decision of whether or not to carry an object after they have picked it up as reflected in the probability of this response (Phelps & Roberts, 1989; Whishaw, 1990; Wallace, 1997). Thus, in Experiment 1, one rat did pick up a dry pledget initially on Trial 1 of deprivation, but this object was then dropped, and the rat moved to the side with the water pledgets, picked one up and carried it.

The results of Experiment 2 are relevant in this connection because they show that, even if one assumed that water retrieval is a specific adaptation, one could not explain the sudden shift in preference in Experiment 1 on this basis. In this case, rats in the second experiment would have shown an immediate retrieval preference in favor of the wet pledgets without a period of trial and error learning.

These arguments suggest that retrieval of wet objects in Experiment 1 under conditions of thirst was the result of an immediate computation, or 'deduction', based on information about the current situation. Some of this information, i.e., the characteristics and general location of objects in the alley, would have been acquired in previous trials. Other critical information, such as the state of water balance, was presumably based on direct detection.

It must be emphasized at once that the term "deduction" in this context carries no implication of any particular 'cognitive' processes on the part of the rat. In fact, an hypothesis to be presented shortly about the nature of this deduction has a distinct S-R (stimulus- response) flavor. One way to orient one's thinking here is to note that an S-R relation is a kind of deduction. For example, a simple stimulus-response relation like:

$$S_{water} \Rightarrow R_{retrieval}$$

(where "retrieval" is shorthand for specific responses such as picking up an object and carrying it that make up the retrieval sequence) can be viewed as a deduction with a single implication, having S_{water} as the antecedent and $R_{retrieval}$ as the consequent. In other words, all that is implied here by the term "deduction" is a conditional response. This is what is meant by the phrase "behavior as deduction"; conditional responding has the features of a deduction, whatever the basis for this association.

Thus, the issue of whether a rat can represent pertinent conditions in a way that is in some sense "declarative" (Dickinson, 1988) is irrelevant to the present argument. As I will show, the deductive capacities in evidence here can be handled within a "procedural" (here, an S-R) framework. On the other hand, the information required for this deduction, that was gained during the initial *ad lib* condition of Experiment 1 without apparent overt manifestation, appears to have the characteristics of declarative knowledge. It is worth noting in this connection that in computer science and artificial intelligence, the meaning and status of the distinction between declarative and procedural information is still controversial: some authors argue that it is basic (Genesereth & Nilsson, 1987), while others note that it tends to evanesce when the computational processes are examined closely (Wegner, 1968; Winston, 1977).

If an S-R framework is sufficient, then why speak about deductions at all? The reason is that, according to the present argument, the rat behaves in a manner consistent with a novel deduction that is appropriate to the situation. In doing this it avoids search, or trial and error, in coming up with a solution to its problem. This may be an interesting example of the principle that inference is generally more efficient than search; more familiar behavioral examples are 'built-in' stimulus-response patterns, i.e., species-typical behavior patterns that do not require learning. (Of course, the latter are not novel in the sense used here.) Under the present assumptions, other kinds of object retrieval, e.g., of sweet-tasting or novel objects, could be carried out through the same form of deduction. An earlier experiment is suggestive in this regard. Gross and Cohn (1954) found that rats fed a vitamin-B deficient diet retrieved normal food pellets in greater numbers than ones made from the deficient diet, when the two were presented together. Although details of behavior at the beginning of the experimental tests were not given, a few rats showed an exclusive preference for normal pellets during this period, so they must have selected them from the very beginning of the condition.

All this suggests that the characterization of object retrieval as a simple (stimulus-) response sequence is inadequate. It may be more accurate to describe it as a limited domain of inference expressed in terms of a particular behavior pattern.

An explanation for this deductive ability can be given that is fairly straightforward in principle. We are assuming that the rat's behavior does not embody the following proposition at the outset,

$$\forall_x \left[\left(wet(x) \& \ transportable(x) \& \ THIRST \right) \right] \Rightarrow retrieve(x) \qquad (1)$$

where x is some perceived entity, "wet" and "transportable" are features of x, and THIRST is a state of the animal, here represented as an atomic proposition. (Again, this proposition is meant to represent relations embodied in the rat's behavior in some situation; it is not meant to imply that the rat can 'think' about the situation in this way.) However, there is much evidence to indicate that wetness and other properties such as sweetness and novelty all have characteristics referred to as incentive or value under the proper conditions (thirst, in the case of wetness) (Toates, 1986). This can also be represented by an implication:

$$\forall_x \left[\left(wet(x) \& \; THIRST \right) \Rightarrow incentive(x) \right] \tag{2}$$

If we then assume that the following implication is already embodied in the machinery of object retrieval,

$$\forall_x \left[\left(incentive(x) \& \; transportable(x) \right) \Rightarrow retrieve(x) \right] \tag{3}$$

then retrieve(x), i.e., the overt act of retrieving object x, can be derived from the antecedent of proposition (1) by appropriate substitutions.

The point of the above argument is that, by recoding properties like wetness or novelty into a more general property like incentive and by tying retrieval to this more general 'term', we get 'deductions' in the form of behavior that do not have to be selected for as such. From another perspective, the rat has arrived at a general rule of thumb for retrieving objects in terms of incentive or value instead of more specific rules of thumb in terms of specific object properties, and from this rule it can deduce procedures consistent with policies that it has not had to implement during its previous ontogenetic or phylogenetic history. One must, of course, assume that the incentive-retrieval linkage was originally selected for in some specific context. Given more than one type of object that could be profitably retrieved (e.g., food items and nesting material), an incentive encoding may have led to simpler and more efficient elicitation of object retrieval, as well as providing a common basis for choosing between objects (Wallace, 1997). This latter function may have been a critical selective factor, since a common incentive could support consistent object preferences based on quantitative variations in this factor, while it is not clear that this could be accomplished easily (or at all) given a set of specific adapations (eg, sweetness-retrieval, water-retrieval). Moreover, a common incentive factor can (potentially) allow the organism to override the input from an incentive that is immediately present if there is something else in the environment that is preferable, a capacity shown by Norway rats (Wallace, 1997).

It should also be kept in mind that incentive processes serve other functions than supporting object retrieval (*cf.* Toates, 1986), so these processes may have existed before their association with this behavior. Hence, there is nothing in the consideration of possible evolutionary pathways that makes the emergence of a capacity for novel behavioral deductions impossible or even unlikely. To my mind, the alternative, that water retrieval was selected for directly, seems far less tenable.

The deductive properties of object retrieval by Norway rats make this behavior a kind of generalist strategy. However, the present account differs from commonly noted instances of such strategies in the following way. Consider the specialist/generalist dichotomy in the domain of feeding, e.g., a herbivore versus an omnivore. The main difference in this case is between a system specialized to digest certain types of vegetable matter efficiently and a less efficient system that can handle a greater variety of foodstuffs. This difference involves an important tradeoff with respect to adaptability: the generalist does not have the ability to forage efficiently for certain foodstuffs, and here it is outcompeted by the specialist, but if these foods are not available, the specialist perishes. In contrast, in the present case the generalist gives up very little - some extra neural apparatus to recode object features and slightly longer times for decision making, both of which appear to be inconsequential. This gives good reason for expecting that, if the capacity to make behavioral deductions in more general terms evolves, it will displace more specialized strategies. The latter are not adapted to as many conditions and will not outperform the generalist strategy sufficiently in any condition so as to support existence in a separate niche. Therefore, incentive functioning in this generalized fashion may be a fairly common feature of animal behavior.

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