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Abstract

When challenged with a cognitive task, rats demonstrate a behavioral fexibility in use and preference of sensory modalities. The present study describes visual and tactile behaviors used by rats in a two choice object discrimination swimming task. The task was designed to preclude use of other sensory modalities and could not be solved via spatial strategies. Fourteen rats learned to criterion a series of 10 discrimination problems. Rats exhibited three stereotypic visual and two stereotypic tactile behaviors over the course of the study. Data analyses indicated that rats demonstrated these behaviors more frequently as they became more familiar with the task. However, once they became proficient, a significant increase in tactile behaviors paralleled a significant decrease in visual behaviors. Reports on the use of visual and tactile behaviors by wild rats are discussed to help interpret the laboratory data from an evolutionary perspective.

Introduction

When exploring the cognitive abilities of animals in a laboratory setting, it is imperative that psychologists be sensitive to specific behaviors and sensory processes of the species under investigation (Lorenz, 1952; Breland and Breland, 1961; Bolles, 1970). From this perspective, the present report describes the development of a swimming task designed to assess the ability of Norway rats to form a learning set concept via use of visual and tactile behaviors. Behavioral procedures from a previous study are presented to familiarize the reader with our task, and then a recent experiment is presented that quantifies the use of visual and tactile behaviors by rats over the course of the learning process. Results are discussed relative to the use of these sensory behaviors by wild rats.

In the psychological literature, learning set is considered a cognitive, conceptual type of learning in which animals demonstrate an increase in performance across a series of novel discrimination problems (Harlow, 1949; Warren, 1965; Schrier, 1984). Mammals such as apes, monkeys, cats, and dogs have demonstrated such learning, as have certain species of birds. Similar studies with rats show them quite capable when challenged with olfactory, gustatory, auditory, or spatial discriminations. However, numerous attempt to demonstrate visual discrimination learning sets have not been conclusive, and few data are available for tactile discriminations (for review, see Wiebers, 1992). Thus, our original objective was to design an object discrimination task for rats that might be more conducive to their use of visual and tactile sensory modalities.

In designing our task, we opted to use a large circular watering trough for our testing arena because rats are known to be natural swimmers (Barnett, 1975; Morris, 1981). Moreover, while rats are motivated to find a way out of water, this procedure is far less invasive than traditional motivational methods such as shock or food deprivation. During learning, our rats would be started at one end of the pool, on the other side of which were two visible objects (plastic or metal junk objects of varying size, form, and luminance). These objects were affixed to underwater escape platforms. If a correct choice was made, the animal could displace the object and escape from the water. Conversely, the platforms and objects could be lowerd below the surface of the water if an incorrect choice was made, thus forcing the animal to continue swimming. The task could not be solved via spatial strategies, and precautions were taken to preclude use of any sensory modalities except visual and tactile processes. Wiebers (1992) provides methodology for controlling use of auditory and olfactory cues in our swimming task.

Our original study used a learning to criterion procedure in which rats learned a total of 51 novel discrimination problems. Rats learned at their own pace, and while there were admittedly individual differences in performance, group performance was significantly above chance, thus suggesting evidence of a learning set concept using visual and tactile behaviors. However, two other findings of the original study are particularly relevant to the current report. First, certain problems proved to be of inherently low, moderate, or high difficulty regardless of when they were encountered during the learning process. We identified three respective difficulty clusters of five problems each, via data analyses and four decision rules. Second, rats consistently demonstrated three stereotypic tactile behaviors over the course of the study. These sensory behaviors are the focus of the following experiment and will be discussed as they relate to the learning process and also to the behaviors of wild rats.

Materials and Methods

Fourteen adult male Long Evans hooded rats were used. From the time of weaning, they were group housed and received frequent social interaction sessions with humans and each other as part of an inter- and intraspecies socialization process. Rats always had food and water available and received a variety of foods in addition to the standard Purina chow diet.

A general overview of the swimming task has already been given in introducing this paper. For a detailed description of the apparatus and specific procedures, see Wiebers and Hothersall (1994). For purposes of this report, only a few design issues are of particular importance. First, this study was conducted in two phases. In the first phase, rats were randomly assigned to one of two groups, Low Difficulty (LD rats) and High Difficulty (HD rats). During this learning phase, LD and HD rats received five low or high difficulty problems, respectively. For the second learning phase, all rats received five identical moderate difficulty problems. Animals proceeded at their own pace and were required to make 10 correct choices out of 12 trials during a single day's session before moving on to their next problem.

The second design issue is critical to this paper and involves the observation and recording of stereotypic visual and tactile behaviors. Five specific behaviors, with the first three being visual and the last two being tactile, were defined as follows:

1) VTEs (Vicarious Trial & Errors) – en route to the platforms, the rat exhibits a multiple series of head turns directed at each of the two objects (Tolman, 1948).
2) VEERs – the rat begins his approach directly toward one platform and then makes a sharp body turn in the direction of the opposite platform.
3) SPINs – en route to the platforms, the rat stops in the water, does a compact, full, body spin and then resumes his approach.
4) PUSH AWAYs – upon arrival at a platform, the rat pushes off the underwater platform and/or object with his front paws.
5) LEAPs – upon arrival at a platform, the rat pushes off the underwater platform (possibly making body contact with the object) with his rear paws and proceeds to the other platform – often, becoming completely airborne.

These behaviors were observed consistently in our original study and were demonstrated by all of the rats. However, individual rats tended to have preferred behaviors. It should be noted that these behaviors were regularly observed on both correct and incorrect trials. These behaviors were operationally defined prior to data collection in the current experiment and were recorded systematically as they occurred.

Results

All rats successfully solved their respective 10 problems. Figure 1 depicts sessions to criterion for LS and HD rats (i.e., number of sessions needed to attain at least 10 correct choices within a single session). While there are several interesting results that could be discussed from a psychological learning perspective, it is sufficient for the reader to note the learning curve demonstrated by the HD rats. Since their significant decrease in sessions to criterion across the first five problems was not attributable to decreasing problem difficulty, these rats clearly demonstrated a learning set concept using visual and tactile behaviors. However, the primary focus of this paper is the use of these behaviors by rats in our task.

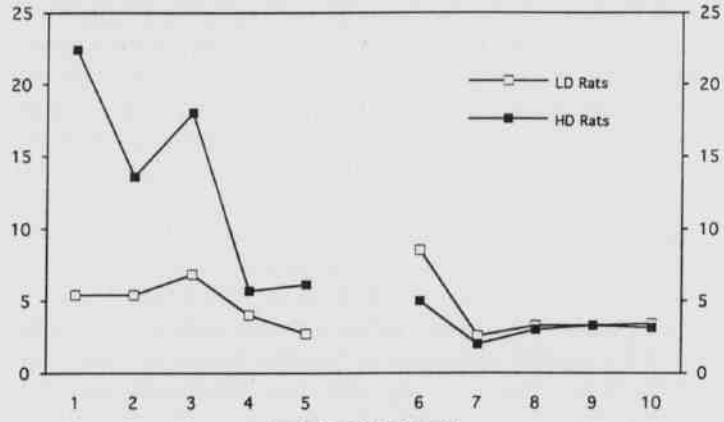

Fig. 1. Sessions to criterion across chronological problem.

All rats exhibited the five stereotypic behaviors over the course of the study, and no new or novel behaviors were observed. Percent of trials in which the behaviors were observed was used as a dependent measure for analysis. Visual and tactile data were initially analyzed separately. For each modality, a between/within (group by chronological problem) ANOVA was conducted for each of the two learning phases. In each modality analysis, no differences were detected between LD and HD rats in either learning phase, nor were there any significant interaction effects. However, significant effects were detected for prevalence of both visual and tactile behaviors across chronological problems in both learning phases. Use of both visual and tactile behaviors significantly increased during the first learning phase, $F(4, 48) = 3.52$, $P < .02$ and $F(4, 48) = 5.65$, $P < .001$, respectively. Curiously during the second learning phase, a significant decrease in visual behaviors, $F(4, 48) = 3.83$, $P < .01$, contrasted with a continued significant increase in tactile behaviors, $F(4, 48) = 3.19$, $P < .02$.

Given the lack of any differences between LD and HD rats with regard to use of visual and tactile behaviors in our task, we thought it interesting to directly compare the utilization of these sensory behaviors by rats over the course of learning. In so doing, we used the data from all 14 rats and conducted two-factor repeated measures ANOVAs for the two learning phases, specifically sensory modality by chronological problem. Figure 2 depicts percent of trials in which visual and tactile behaviors were observed across the two learning phases. During the first learning phase, a significant effect of sensory modality indicated that rats were relying on visual behaviors to a greater extent than tactile behaviros, $F(1, 13) = 4.76$, $P < .05$. In addition, a significant effect of chronological problem reflected a steady increase in use of both sensory behaviors, $F(4, 52) = 10.89$, $P < .001$. For the second learning phase, the only significant effect was an interaction between sensory modality and chronological problem, $F(4, 52) = 4.75$, $P < .01$. As can be seen in Fig. 2, this finding is particularly interesting because it indicates that once rats became proficient in our learning task, a continued preference for tactile behaviors coincided with a significant decrease in visual behaviors.

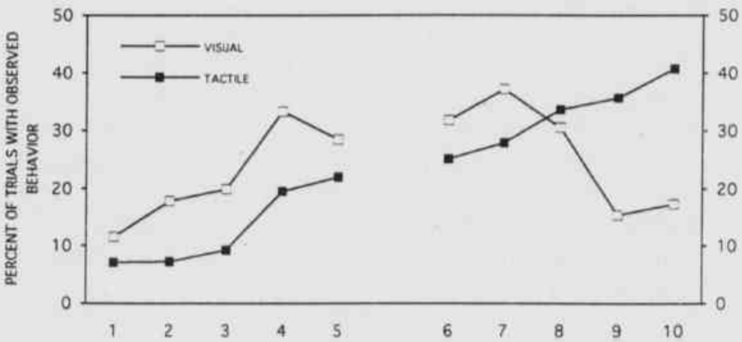

Fig. 2. Percent of visual and tactile behaviors observed across chronological problem.

Discussion

We have described a laboratory situation which requires Norway rats to utilize visual and tactile sensory modalities in solving a cognitive discrimination task. These data provide evidence that rats exhibit a certain behavioral flexibility when conditions require them to do so. In psychological learning theory, rats are often described as olfactory or spatially oriented animals, and are often profiled as having notoriously poor visual systems. Moreover, they are often lauded as having well developed auditory systems and extremely sensitive vibrissae for spatial detection; yet little attention is given to their ability for object manipulation. While there are valid reasons for such contentions, our study has provided evidence that visual and tactile modalities in rats are probably better developed than is generally acknowledged. We can further develop our case by addressing behaviors of both new and old world rats under natural conditions. Whereas wild rats have occasion to rely on visual and tactile behaviors for survival, we might expect laboratory rats to share a similar behavioral repertoire.

As exemplars of new and old world rats, let us use the wood rat (*Neotoma floridana*) and Norway rat (*Rattus norvegicus*), respectively. First, consider predator situations when visual behaviors might be necessary for survival. As a wild rat, visually detecting the silhouette of an appoaching raptor in the absence of olfactory, auditory, or spatial warning signals could be a matter of utmost significance (McFarland, 1985). Moreover, many predators will approach their prey from down wind, suggesting a rat being hunted must rely primarily on auditory and visual simuli. Additional examples might include the need to visually seek out shelter when confronted with an unexpected emergency encounter in a strange locale. These are certainly realistic situations for rats in rural communities. It is easy to imagine numerous other situations encountered by the often more urbanized Norway rat whose primary predators are humans.

Tactile behaviors and object manipulations are also of survival value for wild rats. Consider rats living along the banks of the Po River in Italy. Part of their food acquisition involves diving to the bottom of the river and retrieving molluscs (Galef, 1980). These animals are certainly using tactile and perhaps visual behaviors in their efforts. Also, Twigg (1975) describes a "search grasp" behavior used by rats, wherein they sift dirty or muddy water through their hands in hopes of finding morsels of food.

Another aspect of object manipulation involves the nest building behavior of wood rats, perhaps better known as pack or trade rats. These rats are continually bringing objects back to their nest sites, supposedly to reinforce their homes. However, if they happen to wander through your campsite, they will readily leave a hand-

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some stick or stone in trade for your shiny new Swiss army knife or pocket watch (Caras, 1967). Wild Norway rats are also known for their knack of collecting seemingly useless objects, though they do not construct the elaborate nests of their new world counterparts (Barnett, 1975). Three possible explanations may be given for these types of behaviors in wild rats. Perhaps object manipulation is reminiscent of what has been called their "hoarding instinct", though Barnett (1975) argues against such a simple explanation. Another thought is that while wood rats might have a legitimate use for objects in nest building, this analogous behavior in Norway rats may have become a vestigial behavior after their liaison with *Homo sapiens*. Finally, Renner (1988) argues that exploratory behavior is of critical survival value in rats, and furthermore, this behavior not only consists of movements through space, but also tactile manipulations of novel inanimate objects. Approaches to objects vary between laboratory and wild rats, but nevertheless, object manipulation appears a necessary behavioral component (Dewsbury and Rethlingshafer, 1973).

Having discussed the significance of visual and tactile behaviors by wild rats, we can draw the following conclusions from the laboratory data presented in this paper. First, we suggest that if animal behaviorists observe depressed performance by their rats in learning tasks requiring visual and tactile modalities, they should be cautious in attributing such data to poorly developed sensory processes. Rather, they might consider that the task was not properly designed with regard to the rat's behavioral and biological repertoire. Second, our data suggest that rats probably have a preferential hierarchy with regard to use of their sensory modalities. For example, rats in our study demonstrated a significant preference for use of tactile behaviors once they became proficient at the task. Thus, they will exhibit a behavioral flexibility in adapting to various environmental demands. Finally, it would be interesting to explore whether wild rats in natural aquatic situations exhibit the stereotypic behaviors observed in our study. Perhaps some or all of these behaviors might not only be task specific, but species specific as well.

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