VALIDITY OF USE OF A Y-MAZE TO DETERMINE A FORAGING STRATEGY OF CATTLE

E. Hosoi[1], L. R. Rittenhouse, D. M. Swift, R. W. Richards[2] and H. Yano[3]

Range Science Department, Colorado State Universtiy, CO 80523, USA

Summary

Validity of use of a Y-maze for determining a foraging strategy of cattle was investigated with the object of establishing a procedure of testing foraging strategies of large herbivores. Cattle were placed in a start box of a Y-maze, forced into either goal arm and allowed to consume half of the feed at the end of the arm. Then, cattle were returned to the start box and allowed to choose either arm in the second half of a trial. This time animals were allowed to deplete the feed in the goal arm they chose. A return to the previous arm was recorded a "stay". Choice of the other arm was recorded as a "shift". Shift strategy was not observed. Rather, their behavior appeared either random or stay. However, it might have been caused by inappropriateness of the application of the apparatus and/or the procedure used in the study of foraging behavior of rats. Although the existence of lateral preference was suggested, further study with an elaborated procedure will be necessary to investigate foraging strategies of cattle.

(**Key Words** : Cattle, Foraging Strategy, Y-maze, Win-shift, Win-stay)

Introduction

Y-mazes and T-mazes are widely used for various studies such as lateral preference, shift/stay strategy and spontaneous alternation behavior (SAB).

Lateral preference is a tendency of the animal to prefer one side to the other when it is given a chance to choose either a right goal arm or a left goal arm in a three arm maze. A T-maze was used to determine lateral preference in sheep (Hansen et al., 1978). They suggested the existence of lateral preference in sheep.

Shift/stay strategies are foraging strategies to start a new foraging expedition discussed by Olton et al. (1981). The win-stay strategy is the behavior of returning to the location where the animal obtained feed most recently. It is appropriate if feed is concentrated and dependable. The win-shift strategy is the behavior of seeking feed at a different place each time. It is appropriate if feed is dispersed in the environment, rapidly depleted, and requires time to be replenished (Davey, 1989). Alternating behavior in rewarded animals was first observed by Hunter (1914) who observed one particular rat which alternated only after it obtained feed. Tolman (1925) also found similar behavior in his rats. However, the win-shift strategy of rats as a species was not investigated until 1981 (Olton et al., 1981).

Spontaneous alternation behavior is a specific type of behavior of animals observed in a three arm maze, in which every time an animal runs through a maze it chooses the opposite goal arm to the one chosen last time. In the most studies of SAB, sated animals are used and they are not rewarded (Richman, 1989). This behavior was observed in rats (Douglas et al., 1972), mice (Petchkovsky and Kirkby, 1970; Syme and Syme, 1977), rabbits (Hughes, 1973), hamsters (Hughes, 1988) and other animals. However, it is not known if SAB occurs in domestic animals such as pigs, goats, sheep, cows, horses, and dogs (Hughes, 1989).

Out of these three types of behavior, the shift/stay strategy is most directly related to range management. If it is possible to test a shift/stay strategy of cattle, it may help to predict the movement of a cattle herd grazing in a pasture. Then an ecological impact of grazing by cattle will be predicted and a better rangeland may be designed. For instance, if cattle tend to stay, they may deplete feed

[1]Address reprint requests to Dr. E. Hosoi, Department of Biological Science, Faculty of Agriculture, Yamaguchi University, 1677-1 Yoshida, Yamaguchi 753, Japan.

[2]Psychology Department, Colorado State Universtiy, Fort Collins, CO 80523, USA.

[3]Department of Animal Science, Faculty of Agriculture, Kyoto University, Sakyo-ku, Kyoto 606-01, Japan.

Received February 24, 1994

Accepted November 18, 1994

resource in a particular area while there are unused good pastures around. Such a risk can be eliminated by encouraging animals to move before they cause overgrazing.

Olton et al. (1981) showed that rats use a win-shift strategy, using a Y-maze. It is considered that SAB reflects a win-shift strategy because SAB occurs in sated animals (Dember, 1989). If that is the case, mice, rabbits, hamsters and other animals that show SAB, as well as rats, can be predicted to use a win-shift strategy. However, since SAB in cattle is not ever investigated, their strategy can not be predicted from the strength of their inherent tendency to alternate. Besides, if cattle show SAB, it is not known how much their behavior is affected by such an instinctive tendency.

Cattle were expected to use a win-shift strategy because it is considered more suitable in their environment, where feed resources are widely dispersed and takes time to be replenished once it is depleted. However, a procedure of investigating foraging strategies of large herbivores has not been established yet. It is not known if a Y-maze apparatus is applicable to cattle as well as to rats. In the present study, the validity of use of a Y-maze and the procedure used by Olton et al. (1981) for a study of foraging behavior of cattle was investigated.

Materials and Methods

To minimize the effect of visual cues in the landscape on animal performance the maze was located inside a barn about twenty meters from a corral where cows spent most of their time when they were not in the maze. The maze was made of weld-wire panels 1.5 m high (figure 1). A gate was placed on the front side of a start box. The gate of the start box was raised by pulling on a rope attached to the gate and running through a pulley attached to the ceiling of the barn. The gate was opened from behind a black plastic sheet placed between two goal boxes. The black plastic sheet prevented cows from seeing the manipulations of the goal boxes while they were in the start box.

Four free grazing cows (C1-C4), all of which were mixed breed of more than 10 years old, were used. Before phase 1 was started, cows were led into the barn and trained to expect feed at the end of each arm (goal box) in the maze. Only one animal at a time was allowed to enter the barn and the maze during the study phases. However, during the training period, two cows were paired until they got accustomed to the maze.

The feed used in the study was a commercial mixture of grains and supplemental vitamins and minerals, which contained > 11.0% crude protein, > 2.0% crude fat, and < 13.0% crude fiber.

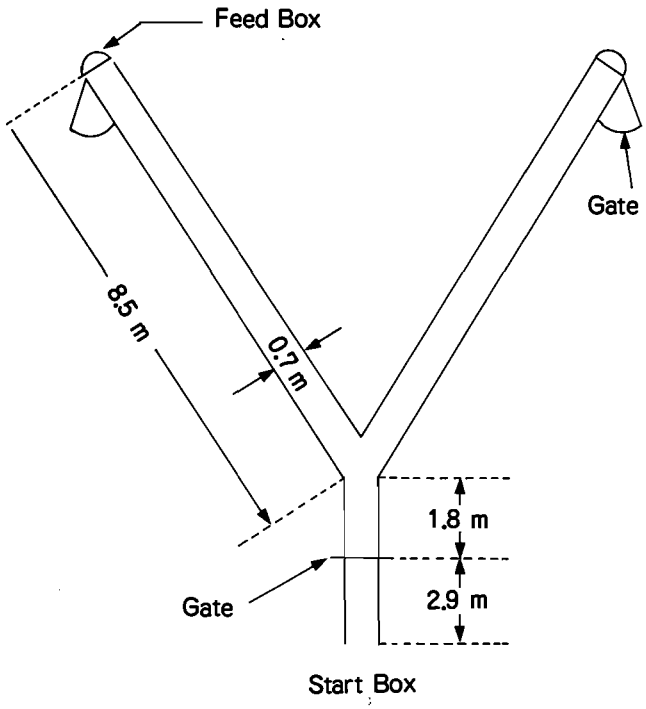

Figure 1. The Y-maze used in the study.

In phase 1, thirty-two randomly selected, forced choices were used to extinguish memory for previous feeding regimens and to reinforce the expectation of feed at the end of each arm. One kg of feed was placed in the goal box at the end of each arm. Cows were forced into a randomly selected arm on the first half of the trial. They were forced to enter the chosen arm by blocking the other arm. Cows were removed from the maze after one half of the feed (i.e., 0.5 kg) in that arm was consumed. An amount of feed equal to that left in the previously-entered arm was placed in the other arm. Cows were kept in the start box while manipulating goal boxes. Cows were again forced into a randomly chosen arm during the second half of the trial in the same manner as the first half, and were permitted to consume all of the feed in that arm. In this way cows would learn to expect a given amount of feed at the end of each arm, but would not be biased toward a win-stay or win-shift strategy. In this phase two forced choices were given in each trial and three trials were given to each animal in a session. Each session took about four hours. Usually two sessions were given in one day. Morning sessions started at 08:00 AM and afternoon sessions started at 04:00 PM. Each animal completed thirty-two trials.

In phase 2, the cows were forced into a randomly

chosen arm in the first half of the trial. Goal boxes contained 1 kg of feed. After consuming about half of the feed in that arm, they were placed back in the start box. The same amount of feed as that left in the previously visited arm was put in the other arm. Then they were allowed free access to either arm. Thus, one forced choice and one free choice was given to each animal in a trial. Trials were repeated eighteen times. As in phase 1, one session included three trials per animal, morning sessions starting at 09:00 AM and afternoon sessions starting at 04:00 PM. One session took about three hours or about fifteen minutes per trial.

Results of phase 2 were analyzed separately for each animal. The behavior of each cow was examined using the binomial test (Zar, 1974) to determine if she showed a lateral preference on the frist choice, and if her behavior on the second choice was random, win-shift or win-stay. When cattle did not exhibit a lateral preference, according to the binomial test, the one-sample runs test (Zar, 1974) was used for further analysis. For instance, if a cow chose the right arm for the first nine trials and switched to the left arm for the next nine trials, her behavior was systematic. But the binomial test cannot tell the difference between such systematic behavior and totally random behavior. The one-sample runs test solves the problem. It tells if the cow chose an arm in a random fashion or not. The word "neutral" was used to describe the behavior of a cow that did not show a preference for either the right or the left arm but chose an arm systematically, and the word "random" for a random choice pattern.

Results and Discussion

In phase 2, only C4 showed a win-shift strategy, while feeding behavior of the other cows was random (table 2). However, it also appeared that C1, C2 and C3 ignored the forced choice (first choice) because they tended to return to a certain arm in the free choice (second choice), regardless of which arm they were forced into on the first choice. C1 always chose the right arm on the second choice; C2 chose the right arm during the first seven trials and always chose the left arm for the rest; C3 chose the left arm fifteen times out of a total of 18 trials (table 1). These behavior resulted in the strong lateral preference (table 2). If decision making is not dependent on which arm was chosen on the previous choice, the result will be a win-stay strategy or random behavior, depending on the strength of lateral preference, because, in order to use a win-shift strategy, they have to remember where they went last time and use that information for making a correct choice. If they totally ignored the first half of a trial and still want to use a win-shift strategy, they might have alternated from one trial to another only on the second half of a trial. However, they did not behave like so. There are two possible explanations to this.

TABLE 1. SEQUENCE OF CHOICES OF THE COWS IN PHASE 2

Trial	Cows			
	C1	C2	C3	C4
1	LR[1]	LR	RL[2]	RR[3]
2	RR	RR	RL	LR
3	RR	LR	LL[4]	LR
4	RR	RR	LL	RL
5	LR	LR	LL	LR
6	RR	RR	RL	RL
7	LR	LR	RL	LR
8	LR	RL	LL	LL
9	LR	RL	RL	RR
10	LR	RL	LL	RR
11	RR	LL	LL	RL
12	RR	RL	LR	LR
13	RR	LL	RL	RL
14	LR	LL	RL	RL
15	LR	RL	RL	RR
16	RR	RL	LR	LR
17	RR	LL	RL	LR
18	LR	LL	LR	LR

[1]LR: forced to left in the first half and chose right in the second half.

[2]RL: forced to right in the first half and chose left in the second half.

[3]RR: forced to right in the first half and chose right in the second half.

[4]LL: forced to left in the first half and chose left in the second half.

(1) The intertrial interval was so long (45 min) compared to the interval between two choices in one trial (2-3 min) that the cows recognized one trial as an independent trial from another. Although cattle can associate several locations with feed resources and remember the locations for up to eight hours (Baily et al., 1989), it does not mean that they do not differentiate a few minutes spent in the start box waiting for the second choice and 45 minutes spent outside the barn. If they did

differentiate an intertrial interval and an "intratrial" interval, they would not necessarily alternate even if they use a win-shift strategy. Therefore, only their lateral preferences may have been revealed.

TABLE 2. THE LATERAL PREFERENCE AND WIN STRATEGY OF COWS FORCED INTO A RANDOMLY CHOSEN ARM ON THE FIRST HALF OF A TRIAL, PHASE 2

Cows	Right / left (%)	P-value	P-value of runs test	Lateral preference	Shift / stay (%)	P-value	Strategy
C1	100.0/0.0	< 0.01		Right	50.0/50.0	0.59	Random
C2	38.9/61.1	0.24	< 0.01	Neutral	55.6/44.4	0.41	Random
C3	16.7/83.3	< 0.01		Left	66.7/33.3	0.12	Random
C4	66.7/33.3	0.12	0.50	Random	72.2/28.8	0.05	Shift

(2) The cows failed to recognize that each trial consists of one forced choice and one free choice and is independent from another trial. If this is what happened, they would show their strategy in the sequence of free choices of the second half of a trial. And it is concluded that C1, C2 and C3 used a win-stay strategy, contrary to the prediction originally made. And their lateral preferences were revealed in their strategies.

In either case, a forced choice in the first half of a trial does not affect the decision making of animals on the second choice. The combination of a forced choice and a free choice may be inappropriate for determining the foraging strategy of cattle. However, the method that Olton et al. (1981) used was almost the same as this study. In the former part of a trial, they placed a rat on either goal arm. And in the latter part, they placed the animal in the start box and let the animal choose either goal arm. Their rats alternated in high frequency. The reason why the system that worked for rats did not work for cattle is not sure. It is certain, however, that the direct application of the apparatus and/or the method used by Olton et al. (1981) is not effective in studying foraging behavior of cattle and at least some modifications, such as the introduction of two free choices in a trial, should be necessary. Or something other than a maze may be useful. The natural environments of rats are somehow like mazes: narrow and complicated. On the other hand, the natural environments of cattle are open: completely different from a maze environment. To find an alternative to a maze, further study is necessary.

Acknowledgements

This study was funded by the Colorado Agricultural Experiment Station project No. 156552. Cows were on loan from the Eastern Colorado Research Center near Akron, Colorado.

Literature Cited

Bailey, D. W., L. R. Rittenhouse, R. H. Hart and R. W. Richards. 1989. Characteristics of spatial memory in cattle. Appl. Anim. Behav. Sci. 23:331-340.

Davey, G. 1989. Ecological learning theory. Routledge. New York. pp. 392.

Dember, W. N. 1989. The Search for cues and motives. pp. 19-38. In: W. N. Dember and C. L. Richman (Eds.), Spontaneous Alternation Behavior. Springer-Verlag. New York. pp. 211.

Douglas, R. J., D. Mitchell and D. Kentala. 1972. Spontaneous alternation as a function of maze configuration. Psychon. Sci. 27:285-286.

Hansen, P. J., M. W. Esch, F. C. Hinds, D. E. Brown, A. R. Cobb and J. M. Lewis. 1978. Footedness and lateral preference in sheep. UPDATE 78, A Research Report of Dixon Springs Agricultural Center, DSAC 6, Jan. 1978. pp. 211-214.

Hughes, R. N. 1973. Spontaneous alternation in adult rabbits. Bull. Psychon. Soc. 2:2

Hughes, R. N. 1988. Spontaneous alternation behavior in hamsters. Curr. Psychol. Res. Rev. 6;331-336.

Hughes, R. N. 1989. Phylogenetic comparisons. pp. 39-57. In: W. N. Dember and C. L. Richman (Eds.), Spontaneous Alternation Behavior. Springer-Verlag. New York. pp. 211.

Hunter, W. S. 1914. The auditory sensitivity of the white rat. J. Anim. Behav. 4:215-222.

Olton, D. S., G. E. Handelmann, J. A. Walker. 1981. Spatial memory and food searching strategies. pp. 333-354 In: A. C. Kamil and T. D. Sergent (Editors),

Foraging Behavior: Ecological, Ethological, and Psychological Approaches. Garland STPM Press, New York. pp. 534

Petchkovsky, L. and R. J. Kirkby. 1970. Individual differences, emotionality, and spontaneous alternation in mice. Aust. J. Psychol. 22:75-78.

Richman, C. L. 1989. SAB, reward, and learning. pp. 59-71. In: W. N. Dember and C. L. Richman (Eds.), Spontaneous Alternation Behavior. Springer-Verlag. New York. pp. 221.

Syme, G. J. and L. A. Syme. 1977. Spontaneous alternation in mice: A test of the mere-exposure hypothesis. Am. J. Psy. 90:621-633.

Tolman, E. C. 1925. Purpose and cognition: The determiners of animal learning. Psychol. Rev. 32:285-297.

Zar, J. H. 1974. Biostatistical Analysis. Prentice-Hall. Englewood Cliffs, N. J. pp. 620.