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Behavior and maze learning ability of dairy calves as influenced by housing, sex and sire

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ABSTRACT

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Two-hundred-and-seventy-five calves were allowed to enter a maze to determine how genetic and environmental effects influenced their time, direction first turned upon entry (laterality), and activity in a maze. Calves were put into the maze five times on Days 1, 2 and 3 post-weaning. Diet did not affect time, distance traveled, or activity score in the maze of 53 calves. On Day 2, males were slower to find the food source than females. On Day 3, calves reared in polyvinyl domes initially turned right more often than explained by chance. Activity differed between calves from different sires, sexes, during certain trials, and when the location of the food source was changed. There was nearly a three-fold difference between sire groups in time required to pass through the maze. Maze time was slowest on Day 1, fastest on Day 2, and intermediate on Day 3 (when the location of the food source was changed). Sire groups differed in activity scores on all 3 days. There were significant correlations between maze time and activity scores, between activity score and laterality and between time and laterality on some days.

INTRODUCTION

Learning ability is of special interest to breeders and trainers of companion and working animals, including lactating dairy cows. Albright et al. (1966) trained cows to enter a milking parlor through an auditory stimulus. Cows' movement to a milking parlor from pasture was enhanced by use of a sound device (Kiley-Worthington and Savage, 1978). Murphy and Duarte (1983) found calves responded consistently and positively to voice command, especially to the voices of their normal handlers.

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There is a considerable body of literature concerning the learning ability of laboratory animals subjected to various mazes. Rats' natural instinct to explore passages, caves and tunnels may protect them from predators while obtaining feed, water and shelter. It is uncertain how the cow would react to a larger maze of similar complexity. Wieckert et al. (1966) found calves differed in their ability to associate a visual clue with feed reward in a Y-maze. Schaeffer and Sikes (1971) found heifer calves attained a high level of discrimination in 2–5 days in a Y-maze. Kilgour (1981) used the more complex Hebb–Williams closed-field maze to measure learning ability in Jersey cows and concluded that the tests originally designed for rats could be made more difficult for large animals. Cows' tendency to cross open spaces aids their ability to successfully traverse a maze. Total error scores for cows were much lower than for rats.

Genetic differences may affect the learning ability of different strains within a species. Fuller and Thompson (1960) summarized five studies concerning the selection of maze-bright and maze-dull rats. In four out of five studies, there were clear-cut differences. There was essentially no overlap between bright and dull rats after four to seven generations. The same experiments with cattle would require 18–32 years. Maze-bright animals did not necessarily perform other learning tasks more readily, i.e. the experimentally selected rats had been selected for their ability to learn a specific task, not for overall intelligence.

Kilgour (1981) studied the performance of genetically identical (monozygous (MZ) twin) cattle in a Hebb–Williams closed-field maze. Similarity indices indicated three to four non-related animals could be replaced by one MZ twin pair in maze-learning ability assessment. Purcell (1988) found no significant correlation in the time that MZ twin pairs required to perform a simple task in a T-maze, nor did rearing environment affect learning ability (one calf in each twin pair had been reared in a group of six and the other had been reared in isolation). Warnick et al. (1977) found that isolation-reared calves were significantly more mobile in open-field tests than group-reared calves.

The objective of this study was to determine whether genetic and environmental effects affected calves' performance in a maze that was more difficult to complete than the previously used T-maze.

ANIMALS, MATERIALS AND METHODS

Two-hundred-and-seventy-five Holstein calves (91 males and 184 females) were used in this study. Calves were weaned at 60 days $\pm$ 3 days and put into a group pen on Day 0. On Days 1 through 3 the calves entered a maze 5 times each day. The maze was constructed of straw bales stacked three high. Inside dimensions and a diagram of the maze are given in Fig. 1. On Day 1,

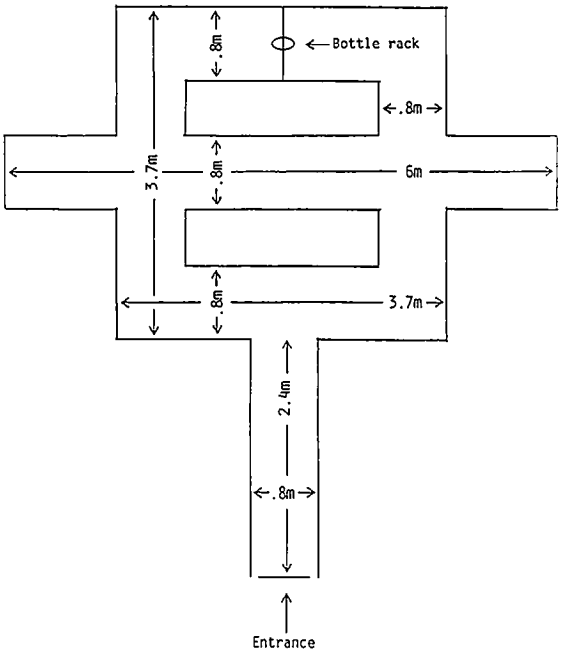

Fig. 1. Calf maze.

milk in a 0.95 l nipple bottle in a conventional bottle rack was hung on the right side of the plywood partition dividing the rear passageway of the maze. Each calf was allowed to taste milk from a second bottle held by an observer at the entrance to the maze. The calf was then put into the maze entrance and a solid door closed behind it. The calf was timed from when it entered the maze until it located the bottle at the far end of the maze. The calf was allowed to suck the bottle for only a few seconds, whereupon it was led out of the maze to repeat the procedure. This occurred five times for each calf each day. If the calf failed to find the bottle within 180 s the trial was terminated, the calf was taken out of the maze and re-entered for the next trial. On Day 2, the procedure for Day 1 was repeated. On Day 3, the procedure for the two previous days was repeated except that the milk bottle was placed on the left side of the rear partition. After the fifth trial each day the calf was allowed to finish drinking the milk remaining in the bottle.

An observer recorded location of the calf during each trial on a maze diagram and also recorded total time to find the bottle (or failure at 180 s). The most direct route to the bottle on Days 1 and 2 required the calf to make one right followed by two left turns. On Day 3, a left and then two right turns were required.

One-hundred-and-seven calves used in the study had been on a microbial additive experiment prior to weaning. They had been fed either 0.95 l whole

milk, 0.95 l whole milk plus 4 g *Lactobacillus acidophilus*, or 0.95 l whole milk plus 4 g *Kluyveromyces fragilis* per head day^{-1}. These calves had been raised in either conventional 1.2 m×2.4 m wooden hutches or 2.4 m diameter polyvinyl domes. Calves in the polyvinyl domes could not see other calves (isolated). The remainder of the calves (168) were reared in the wooden hutches as routine management practice, but not assigned to housing treatment, and received 0.95 l whole milk. All calves received calf starter and alfalfa hay ad libitum, beginning 3 days after birth.

Analysis of the data for effects of sire, sex, housing, (standard hutch vs. polyvinyl domes; Figs. 2 and 3) and diet (microbial additives in milk) was by a general linear models procedure, with time, harmonic mean time, laterality (direction first turned on maze entry), distance traveled, and activity score (distance traveled/log (time)) on Days 1, 2 and 3 as dependent variables. Time for each day was the sum of times for 5 daily trials. The harmonic mean is the reciprocal of the mean of the reciprocal of the observations (Xs). Characteristically, the harmonic mean places more importance on small values of X than on larger values. Thus, for example, one maze run time of 6 s and another of 180 s would have an arithmetic average of 93 s, whereas the harmonic mean would be 11.6 s. Laterality was scored as 1 (left turn upon exiting the entry lane) or 2 (right turn). Distance traveled was estimated by putting dimensions to the calf's trail as recorded on the maze diagram. Min-

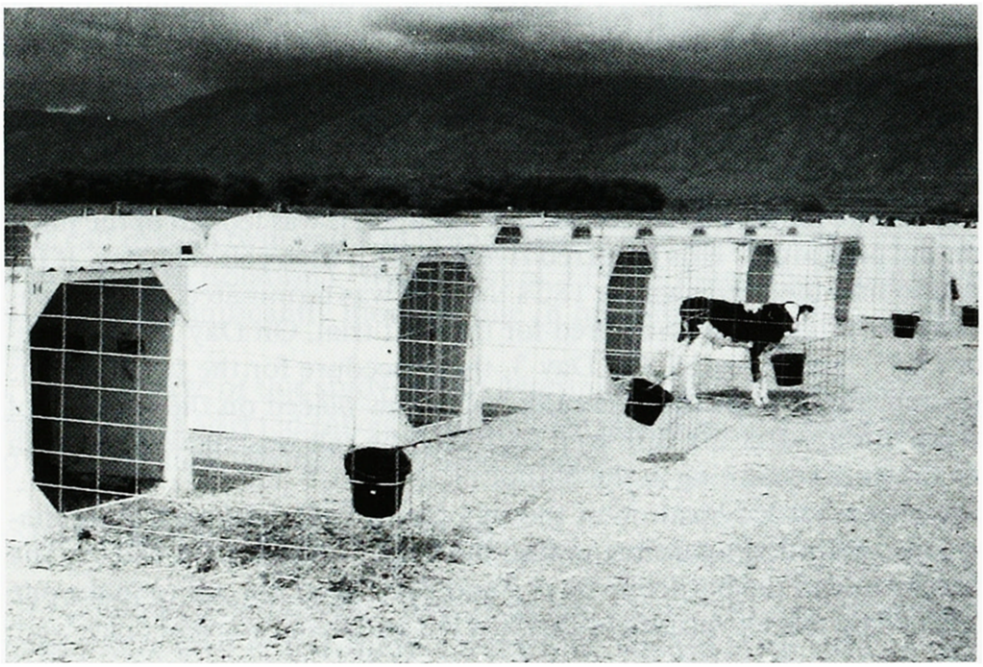

Fig. 2. Standard wooden calf hutch (1.2 m×2.4 m) with a 3.6 m-long wire-mesh fence forming a U-shaped enclosure in front.

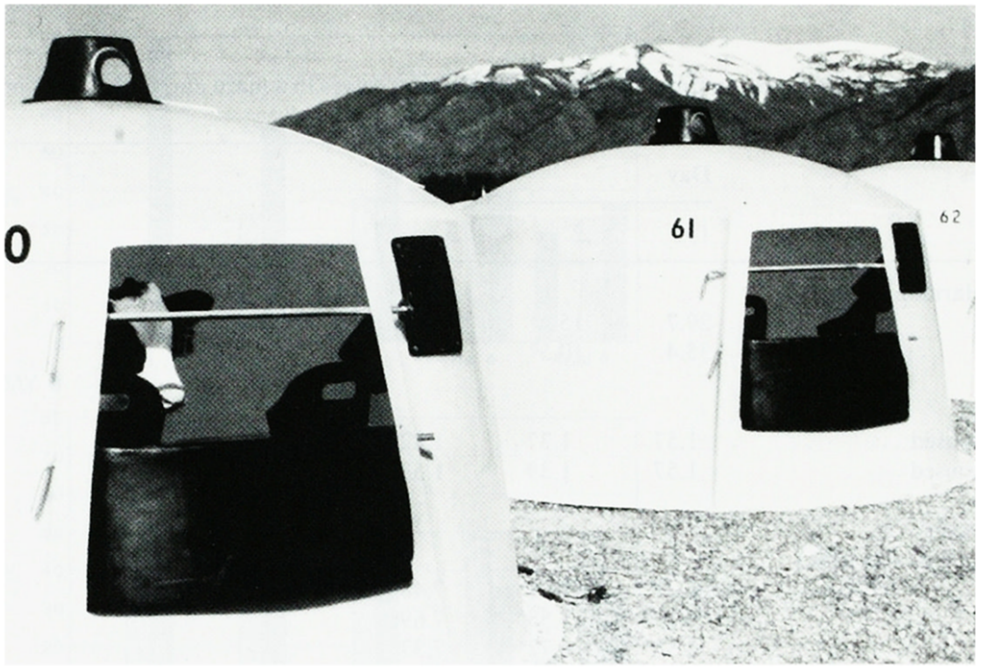

Fig. 3. Polyvinyl dome calf-hutch (2.2 m in diameter and 1.5 m high) with inside feed and water buckets.

imum required distance to reach the food source was 9.8 m. Fifty-three calves (36 female, 17 male) were used in this analysis. These were calves on the feeding trial and belonging to a sire group of at least four. In a second model, data were from all calves from sires with 4 or more calves (17 sires with 181 calves). Dependent variables were as in the first model. Independent variables excluded housing and diet, but included sire, sex, and sire by sex interaction.

RESULTS AND DISCUSSION

Results of analysis of data (53 calves) which included environmental effects (housing and diet) are shown in Table 1. On Day 2, female calves completed the maze in two-thirds the time of male calves. They had learned well from their mistakes on Day 1. There was a tendency for female calves to react more slowly to a new situation as shown by longer maze times on Day 1 and again on Day 3 when the feed source was changed from the right to the left side. Time required to complete the maze differed significantly ($P<0.01$) between Day 1 and Day 2 and increased ($P<0.01$) on Day 3 when the source of reinforcement was changed. Times on Day 3 were faster than on Day 1 ($P<0.05$).

There was a significant ($P<0.01$) effect of housing on laterality on Day 3.

TABLE 1

Effect of sex, housing and sire on time, laterality and activity of calves in a maze during five trials on each of 3 days[1]

Variables	Day		
	1	2	3
Time (Harmonic mean s)			
Male	29.7	15.4[a]	18.3
Female	35.4	10.5[b]	28.1
Laterality			
Dome-housed	1.57	1.37	1.82[a]
Hutch-housed	1.57	1.39	1.53[b]
Activity score (distance (m)/log time)			
Sire 2	6.21[a]	7.21[a]	7.48[a]
Sire 3	6.33[a]	7.53[a]	7.69[a]
Sire 5	6.53[a]	6.72[a,b]	7.37[a]
Sire 12	5.55[a,b]	7.14[a]	7.91[a]
Sire 14	5.08[b]	8.00[a,c]	8.03[a,b]
Sire 16	5.65[a,b]	8.08[a,c]	9.38[b]

[1]Data from 53 calves using Model I analysis.
Means in columns with different superscripts are significantly different ($P<0.05$).

Calves reared in round domes (isolation) tended to turn right most frequently when entering the maze. There was no clear-cut logic to this tendency. Perhaps a lack of rectangular orientation in pre-weaning environment caused an inability of calves to adapt to the most efficient path to feed. This indirect route increased maze time.

Calf activity scores differed among sire groups on each day. Calves from sire 16 were slower on all 3 days. Five of the calves from sire 16 were female, but sex did not influence the activity score. Active calves, through trial and error learning, would almost always find the milk. Some calves appeared to lack motivation in seeking food, even though on Day 1 they would have had no access to milk for over 24 h.

Laterality for all calves is given in Fig. 4. The percentage of calves refusing to go through the maze increased from Trial 1 to Trial 5 daily. By the fourth and fifth trial a few calves stopped trying to find milk. However, only about half as many calves refused to move on the fifth trial on Days 2 and 3 as on Day 1. Calves were apparently more motivated, less satiated, and/or learned that persistence was rewarded. Calves in a T-maze learned most rapidly in 5 trials per session (Wieckert et al., 1966).

The percentage of calves choosing to go right (correct choice Days 1 and

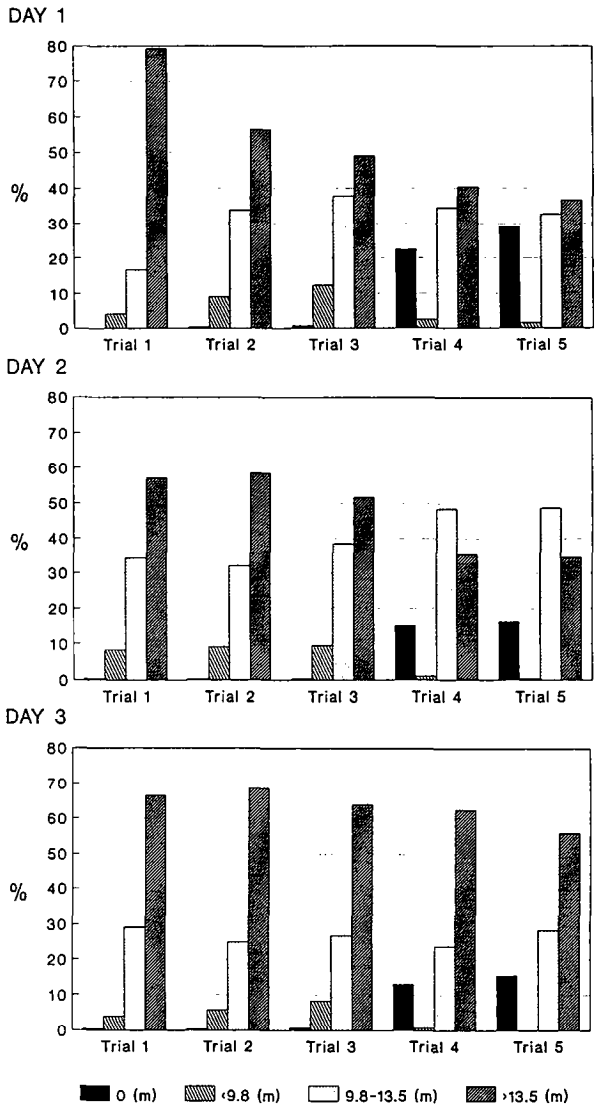

Fig. 4. Frequency distribution ($N=275$) for distance traveled by calves in a maze during five trials each of 3 days.

2) was essentially random. On Day 3, to turn left initially was the correct response. It was not clear why about 10% more calves turned left during Trial 1 on Day 3, nor is it apparent why about twice as many calves turned right (left was correct) during the last four trials. Several calves had apparently learned to turn right for milk on the previous 2 days and did not readily extinguish this behavior when the stimulus was changed.

The only significant ($P<0.05$) difference of sire by sex interaction oc-

TABLE 2

Laterality in a maze during five trials in each of 3 days by sire groups (least-squares means of sire groups with four or more calves each, $N = 181$)

Sire	Laterality					
	Day 1	SE	Day 2	SE	Day 3	SE
1	1.37[1]	0.22	1.60	0.22	1.72	0.22
2	1.51	0.10	1.36	0.11	1.70	0.11
3	1.39	0.09	1.43	0.10	1.65	0.10
4	1.79	0.11	1.48	0.13	1.58	0.13
5	1.51	0.05	1.53	0.06	1.55	0.06
6	1.58	0.15	1.38	0.18	1.52	0.18
7	1.43	0.18	1.72	0.21	1.79	0.20
8	1.60	0.14	1.58	0.21	1.64	0.16
9	1.60	0.18	1.43	0.21	1.67	0.20
10	1.36	0.06	1.55	0.07	1.58	0.07
11	1.48	0.13	1.57	0.14	1.66	0.14
12	1.58	0.12	1.71	0.14	1.66	0.14
13	1.52	0.08	1.55	0.10	1.78	0.10
14	1.55	0.11	1.25	0.13	1.50	0.13
15	1.44	0.12	1.55	0.14	1.82	0.14
16	1.76	0.14	1.20	0.16	1.64	0.16
17	1.70	0.16	1.45	0.18	1.65	0.18
$\bar{X}$	1.52	0.03	1.49	0.03	1.62	0.03

[1] 1 = left, 2 = right.

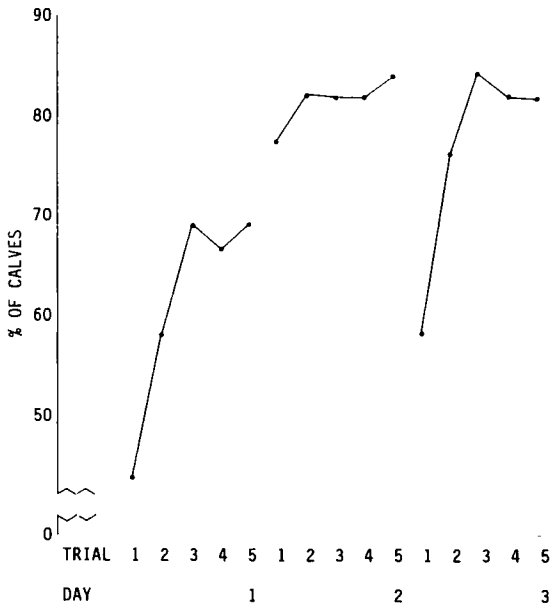

Fig. 5. Calves locating feed in a maze within 3-min trials, 5 times, on each of 3 consecutive days.

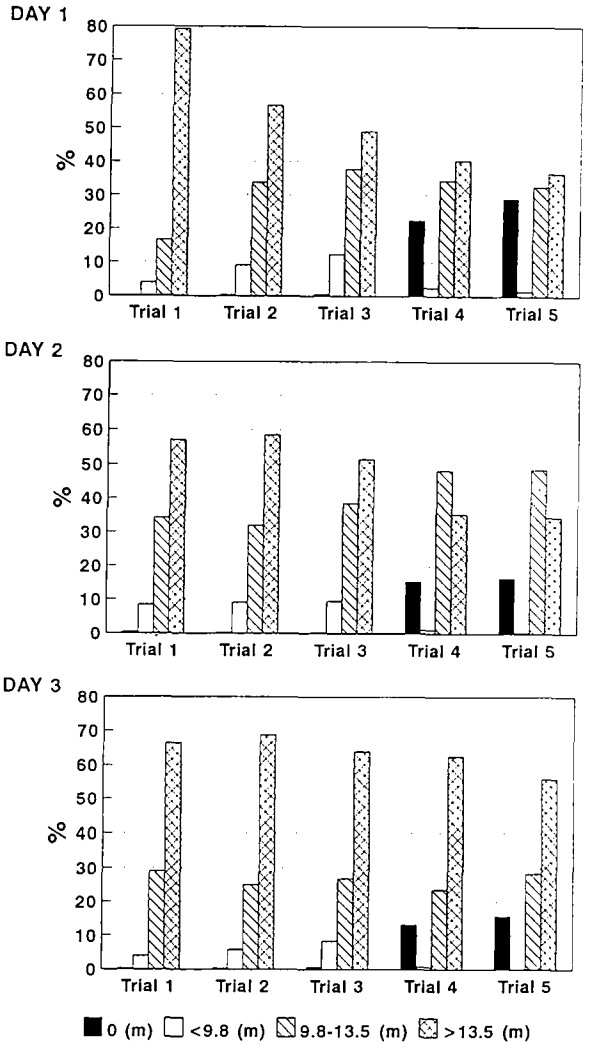

Fig. 6. Frequency distribution ($N=275$) for distance traveled by calves in a maze during five trials each of 3 days.

curred on Day 2. This effect could be attributed primarily to Sires 1 and 8. Daughters of Sire 1 exclusively turned right while sons averaged mostly left (1.2). Daughters of Sire 8 averaged mostly left (1.2) while sons all turned right. Laterality did not differ among sire groups (Table 2). Between Day 1 and Day 2, 5 groups changed from left to right, 7 groups changed from right to left and 5 groups did not change. On Day 3, all groups except group 14 tended to go right, i.e. laterality exceeded 1.5. Calves in five groups changed laterality from left to right from Day 2 to Day 3.

Even though calves required more time to complete the maze on Day 3,

TABLE 3

Total time in maze by sire groups of calves during five trials in each of 3 days (least-squares means of sire groups with four or more calves each, $N = 181$)

Sire	Time in maze (s)					
	Day 1	SE	Day 2	SE	Day 3	SE
1	175.8	25.5	122.9	28.7	112.4	26.3
2	68.4	16.2	15.1	18.2	46.1	16.7
3	69.1	14.2	26.2	16.0	40.3	14.6
4	74.6	18.0	46.5	20.3	88.7	18.6
5	95.5	8.6	52.6	9.6	80.0	8.8
6	139.2	25.5	71.8	28.7	60.9	26.3
7	156.5	29.4	60.8	33.1	55.3	30.3
8	108.8	23.3	82.2	26.2	119.6	24.0
9	88.0	29.4	28.3	33.1	41.0	30.3
10	139.5	9.5	86.3	10.7	91.0	9.8
11	128.0	20.8	60.8	23.4	60.2	21.4
12	86.1	19.9	17.5	22.4	41.0	20.5
13	133.3	13.6	88.9	15.3	108.5	14.0
14	59.6	18.0	16.8	20.3	36.0	18.6
15	95.0	19.5	27.0	21.9	78.0	20.1
16	58.4	22.8	17.2	25.7	35.5	23.5
17	145.0	25.5	78.7	28.7	76.4	26.3
$\bar{Y}$	104.4	6.3	53.5	5.5	73.7	5.3

about the same percentage (82) found milk as on other days (Fig. 5). In a learning test with heifers of the Black Spotted breed, Kovalcik and Kovalcik (1986) found 92% of heifers successfully located the correct feed box during the first four (10 min) tests (2 tests day^{-1}). Once the task was learned and the feed box re-oriented, 85% of heifers located the correct feed box during the remaining six tests. Taking time in test (10 min) vs. time in trial (3 min) into consideration, the percentage finding feed, especially after re-orientation, did not differ greatly in these studies.

The distribution of distance scores for all calves is shown in Fig. 6. The number with no travel increased markedly during the fourth and fifth trials each day. More calves traveled farther on Day 3 after location of the feed site had been changed from the two previous days. Neither sire, sex, nor sire by sex interactions influenced the distance traveled.

A sire effect on learning ability is evident in Table 3. The nearly three-fold difference between high and low sire group times (Table 3) was statistically significant (Table 4). Calves required less time on Day 2 than on Day 1 and most sire groups required more time on Day 3 than on Day 2. Sire groups that completed the maze most rapidly on Day 1 had proportionately faster times on Day 2. There were highly significant ($P < 0.01$) differences between days.

Sire significantly affected maze activity scores (Tables 5, 6). Calves from

TABLE 4

Probabilities associated with least-squares means differences in sire group time in maze

Day 1

	Sire																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		**	**	**	**			*	*			**		**	**	**	
2						*	**	*		**	*		**				*
3						*	**			**	*		**				*
4						*	*			**	*		**				*
5							*			**			*				
6														**			
7												*		**		*	
8														*			
9																	
10																	
11																**	
12																*	
13																	
14																**	*
15																**	
16																	**
17																	

Day 2

	Sire																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		**	**	*	*				*			**		**	**	*	
2								*		**			**				
3										**			**				
4																	
5										*			*				
6																	
7																	
8														*			
9																	
10																*	
11																	
12																	
13																*	
14																	
15																	
16																	
17																	

TABLE 4 (continued)
Day 3

	Sire																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		*	*									*		*		*	
2								**		*			**				
3				*	*			**		**			**				
4														*			
5														*			
6																	
7																	
8									*			**		**			
9													*				
10												*		**		*	
11																	
12													**				
13														**		*	
14																	
15																	
16																	
17																	

* = $P < 0.05$; ** = $P < 0.01$.

TABLE 5

Activity scores[1] of calves in a maze during five trials on each of 3 days (least-squares means of sire groups with four or more calves each, $N = 181$)

Sire	Activity score					
	Day 1	SE	Day 2	SE	Day 3	SE
1	1.8	1.0	4.1	1.1	3.7	1.1
2	6.2	0.7	7.2	0.7	7.7	0.7
3	6.7	0.6	7.7	0.6	7.7	0.6
4	4.9	0.7	6.6	0.8	6.7	0.8
5	6.5	0.4	6.4	0.4	6.8	0.4
6	5.3	1.0	7.6	1.1	5.5	1.1
7	5.4	1.2	5.8	1.2	6.5	1.2
8	5.4	0.9	5.2	1.0	6.3	1.0
9	4.8	1.2	6.8	1.2	8.6	1.2
10	5.5	0.4	5.0	0.4	5.5	0.4
11	5.9	0.8	5.9	0.9	7.4	0.9
12	6.6	0.8	7.1	0.8	7.6	0.8
13	6.9	0.6	5.9	0.6	6.5	0.6
14	5.2	0.7	8.2	0.8	8.2	0.8
15	6.1	0.8	8.3	0.8	8.8	0.8
16	5.7	0.9	8.1	1.0	9.5	1.0
17	5.6	1.0	5.2	1.1	6.9	1.1
$\bar{X}$	5.9	0.2	6.4	0.2	6.9	0.2

[1]Activity score = distance score/log (time).

TABLE 6

Probabilities associated with least-squares means differences in sire group activity score in a maze

Day 1

	Sire																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		**	**	*	**	*	*	**		**	**	**	**	**	**	*	*
2																	
3																	
4					*								*				
5										*							
6																	
7																	
8																	
9																	
10													*				
11																	
12																	
13																	
14																	
15																	
16																	
17																	

Day 2

	Sire																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		**	**		*	*						*		**	**	*	
2										**							
3										**			*				
4																	
5										**				*	*		
6										*							
7																	
8														*	*	*	
9																	
10												*		**	**	*	
11																	
12															*		
13														*	*	*	
14																	*
15																	*
16																	*
17																	

TABLE 6 (continued)
Day 3

	Sire																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		**	**	*	**				**		**	**	*	**	**	**	
2										**							
3										**							
4																*	
5										*					*	*	
6									*					*	**	*	
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8															*		
9										*							
10											*	*		**	**	**	
11																	
12																	
13															*	*	
14																	
15																	
16																	
17																	

*$=P<0.05$; **$=P<0.01$.

Sire 1 had the lowest activity scores and spent the most time in the maze (Table 3). Correlations between maze time and activity score were 0.008, −0.670, and −0.508 on Days 1, 2 and 3, respectively. Correlations greater than ±0.138 were significant ($P<0.05$). The negative correlations on Days 2 and 3 indicate that calves requiring excess time in the maze were actively seeking either an exit or a feed source. The correlations between time and laterality were −0.213, −0.026, and 0.104 on Days 1, 2 and 3, respectively. On Day 1, calves that turned right (higher laterality score) required less time to find food, which was located on the right. The positive correlation between laterality and time on Day 3 shows that calves which turned left completed the maze sooner. Correlations between activity score and laterality were 0.050, −0.226, and 0.224 on Days 1, 2 and 3, respectively. The significant negative correlation on Day 2 and the significant positive correlation on Day 3 confirm that calves that initially turned toward the food source direction had smaller distance/log (time) ratios.

CONCLUSIONS

These data indicate that some learning occurred over the 3-day 15-trial experiment. The results do not allow a comprehensive test of laterality per se, owing to the confounding effect of placement of the food source, which was changed on the third day. The most useful measure of laterality is the first trial on Day 1, the first time calves had entered the maze. Laterality for that trial was essentially random (50.8% right). Learning occurred (but was

thwarted), as shown by the high proportion (62.2% right) of calves that turned right on the third day. Nearly twice as many calves continued to turn right to find food. The fact that the distance traveled was greater on Day 3 than on Day 1 also reflected calves' ability to learn. A dramatic decline in distance traveled during the fourth and fifth trials indicated a weariness or waning of motivation after three trials. It may be more efficient to have fewer trials per day and perhaps conduct trials on additional days. Results substantiate that calves can maneuver through a fairly complex maze and that their ability has a definite genetic component (sire effect). Correlations reflected relationships among time, distance and laterality. Additional study may be of interest in terms of milk yield and activity score in a maze.

ACKNOWLEDGEMENTS

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