Visual Discrimination in Adult Dairy Bulls

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ABSTRACT

Adult Holstein-Friesian dairy bulls were trained to recognize a black disk and then to discriminate between that disk and smaller ones. The bulls learned these tasks, but much more slowly than did dairy calves. Achievement of a consistently high percentage of correct choices varied among bulls because of daily variation in the disposition of the bull, which seemed to affect willingness to concentrate on the experimental task. Nevertheless, all bulls demonstrated learning, and each bull remembered very well what he once had learned. A 36-cm disk was easily detected and discriminated from smaller disks. However, bulls were not able to discriminate between two disks that differed in area by less than a factor of 4. The ability to use visual cues, such as shapes and size of shapes, suggested that the visual system is important in the biology of bulls. The slow learning rate and the variability in the percentages of correct responses were not considered to be an indication of cognitive disabilities in general but rather a reflection of the daily disposition of the bull, which affected his willingness to cooperate.
(**Key words**: adult dairy bulls, learning, vision)

INTRODUCTION

Knowledge of the sensory capacities and associated cognitive processes of an animal and insights into biologically determined preferences and aversions are useful to facilitate handling. This knowledge is particularly useful if the mental disposition and physical power of an animal limits the dominance of humans over it (e. g., handling of adult dairy bulls). Because of sophisticated breeding programs for dairy cattle, large numbers of sires and potential sires are kept at AI centers. These dairy bulls are more difficult to handle than are bulls of other breeds (16). Staff members of AI centers have a strong interest in understanding the behavior of these bulls in order to facilitate handling and to minimize the risk of accidents during the performance of the daily routine. Researchers have begun to investigate the vision of adult dairy bulls and the importance of this sense. Testing the senses of bulls requires the use of various learning paradigms to evaluate the learning capacities. Learning is a precondition of behavioral plasticity, which is very important for domestic animals in general because it enables them to adapt to farm environments.

Scientific knowledge of the vision of cattle is scant. With respect to color perception, for example, data are still contradictory [(5, 7, 17); reviews (9,14)]. Cattle can discriminate between shapes and between patterns (2). Calves are generally able to discriminate squares, triangles, circles, and different types of single or combined bars (2). However, little is known of the ability of cattle to discern the size of an object, which might be biologically relevant. For example, bulls use their large size in threatening postures when they turn around to present themselves laterally to an opponent or an approaching man. This experiment was designed to test whether bulls could identify a small shape and to define their ability to discriminate among different sizes.

Previous reports on sensory abilities and learning behaviors have focused on cows, heifers, or calves. These data are the first from an experiment using adult dairy bulls.

MATERIALS AND METHODS

Four Holstein-Friesian bulls (bulls 1 through 4), which were offspring of selected sires and dams, were 6 to 8 wk of age when they were brought to a specialized testing center in Eickelborn, Germany to undergo a performance test. At the center, bulls were initially kept singly in pens and then were kept in groups of 6 to 8 calves. After bulls were licensed, they were transferred to Rees, Germany, a quarantine station, for a minimum of 30 d. At Rees, bulls were kept in free-stall barns in groups with varying group members. Thereafter, the bulls were taken to the Artificial

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Insemination Center of the Rinder Union West, Kleve, Germany, where 15,000 doses of semen were collected and stored. At Kleve, the young bulls were kept in tie stalls in barns; bulls in adjacent pens were changed frequently. The bulls were then classified as being test bulls in the progeny test. During this 4-yr period, bulls stayed in Lingenbach, Germany and were kept singly in large stalls or in tie stalls in barns; bulls in adjacent pens were changed frequently. At no time during development did the bulls live in stable social hierarchies. Bulls were dehorned as young calves (2 to 4 wk of age) and equipped with a nose ring at the age between 1 and 1.5 yr.

At Lingenbach, the bulls were fed hay in the early morning (0700 h) and in the late afternoon (1600 h). In the morning, bulls also received pellets of balanced rations in calculated amounts (ca. 2 kg). Generally, the bulls had eaten just before each experiment session began. Thus, no bull was hungry, and the bulls were never deprived of feed prior to a session. However, all bulls consumed pellets readily during sessions, regardless of the timing of the morning feeding.

At the beginning of the experiments, the individual bulls were about 2.5 yr old. Training and experiments were conducted at Lingenbach, Germany, in a hall that measured 8.0 × 8.5 m.

During all procedures, the bulls could move almost freely in the hall in which the experiments took place. However, controlling bulls that were not accustomed to moving about freely in a large room was extremely difficult after a procedure. The bulls had a strong tendency to evade the approaching researcher, particularly if he tried to grasp the nose ring (15). Therefore, a very thin, 6-m rope of <400 g was fixed to the nose ring, which allowed the bulls to roam freely while the rope hung loosely. If it was neccessary to bring the bulls under control, the rope could be tightened easily.

Initially, the bulls were trained to notice that two black buckets of equal shape and size (height 20 cm, diameter at the top 24 cm, and at the bottom 16.5 cm) contained feed pellets (ca. 60 g). The buckets were fixed to a bright wall, 1.50 m apart and 0.85 m above the ground.

A trial consisted of the following procedure. The bull was tethered to a pole with his head facing away from the experimental wall. Then, the researcher approached the bull from the left side, detached the bull from the pole, seized the nose ring with his right hand, and turned the bull around. The head of the bull was then oriented toward the wall with the buckets. While holding the rope in his left hand, the researcher released the nose ring and slackened the rope. The bull walked toward the experimental wall to eat the pellets. Three bulls allowed themselves to be touched (however, bull 2 jumped away if the researcher attempted to touch him). For the three bulls, touching and speaking in a friendly manner were used as positive reinforcement for correct performance, along with feeding pellets. To end the trial, the bull's head was removed from the bucket, the nose ring was held with the researcher's right hand, and the bull was brought back to the pole where the trial began.

One training session may have lasted up to 1 h, and a training session consisted of approximately 20 trials. Sometimes bulls were willing to undergo >20 trials, but, in general, the interest of the bulls decreased after this period. Therefore, the standard for the experiments described was fixed at 20 trials per session. Sessions were normally conducted once weekly.

After the bulls were trained for approximately 4 wk, bulls had become calm and familiar with the researcher, and the buckets had been checked for pellets. At that time, the first experiment began. For this experiment, the bulls had to learn that they should consume pellets only from the bucket above which a black disk had been positioned (Figure 1). The same procedure was followed as in the training session except that the bulls were prevented from feeding from the bucket without the black disk. The researcher led bulls away from the wrong bucket and verbally instructed them. Later in these experimental sessions, the verbal instruction alone caused the bulls to avoid the wrong bucket.

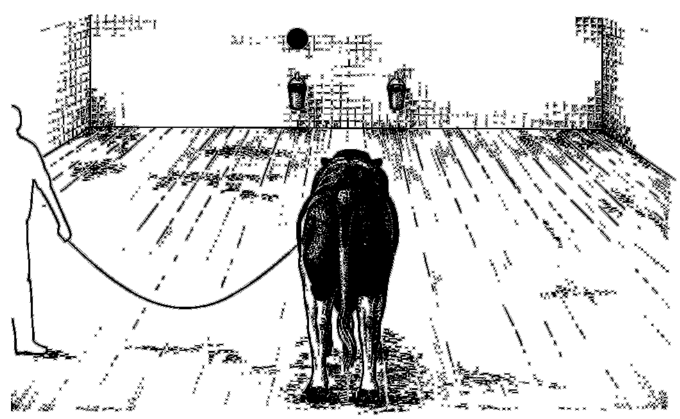

Figure 1. A bull standing in the experimental hall facing the discrimination task. The handler is at the left, and the bull was able to move freely. The rope was slack and only shortened if the bull needed to be brought under control. The distance to the wall measured 8 m. The buckets were positioned 0.85 m above the ground and 1.5 m apart. The black disk displayed above the left bucket had a diameter of 36 cm.

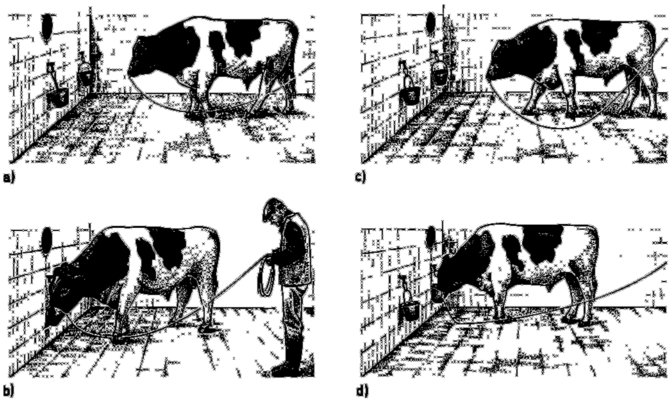

Figure 2. A) Bull 1 in a simple operant conditioning test as he decides to go to the left bucket. Note that eyes and ears of the bull are directed forward. B) Bull 1 eating pellets from the correct bucket. C) Bull 1 during the decision phase of the following trial; the position of the black disk is changed to the right. D) Bull 1 eating pellets from the correct bucket. Illustrations were drawn by Christine Opfermann-Rüngeler from a video film.

When a bull had decided to go to the correct bucket two or three times, the disk position was changed again (Figure 2). Periodically, the position of the disk was determined by chance (by flipping a coin). Regular alteration of the position of the disk after two correct choices did not lead to a better rate of success than random alteration. Bulls were considered to have learned discrimination when success rate reached 70%.

The diameter of the disk was 20 cm during the first 7 or 8 sessions with bulls 1, 2, and 4. Because learning was not obvious during the course of these first sessions with the 20-cm disk, the disk size was changed to 36 cm to accelerate learning, but this change in size had no discernible effect. Bull 3 was trained with the 36-cm disk for all sessions.

The second experiment tested whether the bulls could differentiate between disks of different sizes. In the first session, they were retested for the ability to differentiate the correct bucket, which was marked with the 36-cm disk, from a bucket with no marker fixed above it. In successive sessions, a disk of 9, 18, or 27 cm was displayed over the wrong bucket, and the 36-cm disk continued to be displayed above the correct bucket. In the last session, each bull was again tested with the single, 36-cm disk. The position of the correct stimulus was altered at random.

Tests were conducted principally every day for 1 wk. A test consisted of 20 trials. Once bulls 3 and 4 were tested in the morning as well as in the afternoon (sessions 3 and 4 of the second experiment in each case; Figure 4) because there was the risk that those bulls would have to leave the station on the next day.

The chi-square test (3) was used to determine the learning success rate for each bull during the initial experiment (simple operant conditioning). The first 10 sessions were regarded as training sessions, and the results of those sessions were compared with the subsequent sessions. During the second experiment (discrimination between disks of different size), the continuous decrease in the success rate (the 36-cm disk was discriminated from disks of 9, 18, or 27 cm) was tested with a Mantel-Haenszel test (12).

RESULTS

Recognition of the Bucket with the Disk (Simple Operant Conditioning)

On average, a bull learned the task in 10 to 15 wk. Working every day did not accelerate the learning procedure, and interruptions of 1 or 2 wk had no identifiable effect (i.e., bulls did not forget what they had learned).

The learning curves of the four bulls varied by individual. Bull 1 was mild-mannered and not easily irritated. He walked very slowly and, when approached, always displayed a threatening posture and low frequency vocalization. Nevertheless, bull 1 could be petted without difficulty and followed willingly if led by the nose ring. After 5 sessions, this bull reached the 70% criterion for the first time; however, during the next 5 sessions, his scores were lower (Figure 3). During the 10th session, the bucket on the right side was removed once. However, the bull went to this side nevertheless and turned to the other side ca. 1 m before reaching the wall. During the 11th session (data not included in Figure 3), the bull repeatedly went to the bucket on the right side. Instead of the black disk, a rotating cross or a red disk was displayed in the 12th session to determine whether these objects improved learning. The result was negative (data not included in Figure 3). During the 13th session, the bull suddenly was very cooperative again and reached the 70% success rate with the black disk. Cooperative behavior and high success rate continued for 6 of the following 8 sessions; for 2 sessions, during which the response was slightly under the success criterion, the percentage of correct choices was still higher than would occur by chance. The chi-square test indicated highly significant ($P < 0.001$) learning success (Table 1).

Bull 2 was a nervous, timid bull, although he was very large. He never showed threatening postures toward the approaching researcher, and he retreated if touched. By the 2nd session, the bull had already reached the 70% criterion, but 7 additional sessions were required before this result was repeated (Figure 3). During the following sessions, the bull performed above the 70% criterion five times. During sessions 11 to 15, the 36-cm disk was fixed below the bucket to determine whether this change might facilitate learning; it did not. The chi-square test indicated highly significant learning success rate (Table 1).

Bull 3 was a very submissive bull that typically held his head down the way a calf might do when looking for its dam's udder. He always approached the buckets quickly. For bull 3, the 36-cm disk was used in all sessions for the first experiment. Bull 3 required 8 sessions to reach the 70% criterion, and response remained at this level for 2 more sessions. Performance then decreased dramatically before stabilizing again at 70% (Figure 3). Although the percentage of correct choices is slightly below 70% if sessions numbers >10 are summarized (Table 1), the chi-square test indicated highly significant learning success.

At the beginning of the experiments, bull 4, the smallest bull, was relatively lethargic and perhaps not in prime physical condition. After spending time at pasture, he became agile and difficult to handle because of his aggressiveness. This aggression was controlled by often forcing the bull to walk backwards. Nevertheless, bull 4 performed better than the other bulls, and at the end of this series of experiments, he was behaviorally the most consistent bull; his scores were well above 70% (Figure 3). The fourth bull was the only bull to reach a 100% scoring level. The chi-square test indicated highly significant with success learning (Table 1).

Discrimination Between Disks of Different Size

During the second series of experiments, bull 1 achieved an 80% success rate (Figure 4) during the first session, which retested the ability of the bull to discriminate between the bucket with the 36-cm disk and the bucket with no disk. During the next session, bull 1 achieved a 70% success rate in differentiating this bucket from the bucket with the 9-cm disk. Bull 1 had no problems and discriminated between sizes.

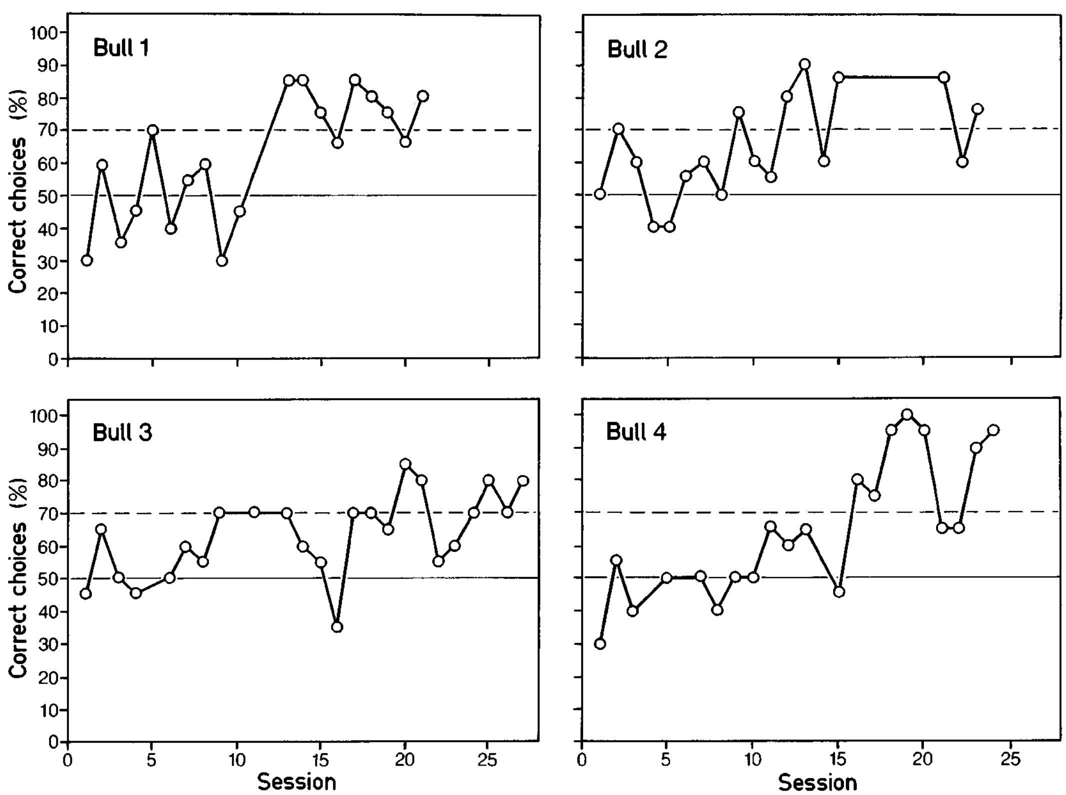

Figure 3. Learning curves of the simple operant conditioning experiments. Each session included 20 trials. The 50% line indicates the chance level; the dashed line at 70% indicates the success criterion. During the last session, the position of the disk was altered at random. Some sessions (sessions 11 and 12 for bull 1; 16 to 20 for bull 2; 5, 10, and 12 for bull 3; and 4, 6, and 14 for bull 4) are not shown because the bulls were not cooperative on those days or because the constraints of the sessions were not adequate.

TABLE 1. Results of the simple operant conditioning experiment using a black 36-cm disk as a positive stimulus.[1,2]

Correct choice	Bull 1	Bull 2	Bull 3	Bull 4
10 Trials				
no./no.[3]	94/200	112/200	88/160	73/160
%	47	56	55	45.63
>10 Trials				
no./no.	139/180	118/160	215/320	199/260
%	77.22	73.75	67.19	76.54
χ^2	36.481	12.139	6.807	41.477
$P <$	0.001	0.001	0.009	0.001

[1]The success rate of the first 10 sessions and the following sessions were compared using a chi-square test with 1 df.

[2]Differences between sessions are significant ($P < 0.01$).

[3]Number of correct choices out of total number of choices.

When the 36-cm disk had to be discriminated from an 18-cm disk, however, bull 1 scored 60%, which was below the success criterion. During the experimental session that used the 18-cm disk, bull 1 required a long time to make a decision, because he hesitated to approach the experimental wall to stand and look at the buckets for many seconds. Therefore, this session was repeated the next day to verify whether the bull had learned to discriminate between the disks. The result was nearly identical (a 40% success rate). On the next day, this bull performed just at chance level, a 50% success rate. At the end of this series of sessions, bull 1 was again tested with the single 36-cm disk, and he reached the success criterion (70%). The Mantel-Haenszel test proved that the continuous decrease in the rate of success in the comparison of the 36- with the 9-cm disk to the rate of success in the comparison the 36- with the 18-cm disk (Table 2) was significant.

Bull 2 began with a 75% success rate when the 36-cm disk was displayed over the correct position and when the position of the bucket was changed at random (Figure 4). The same result was observed on the next day when the 36-cm disk was the correct choice and a 9-cm disk was the incorrect choice; again the position was altered between trials at random. Bull 2 chose correctly between the 36- and 18-cm disks in only 60% of the 20 trials. As was true for bull 1, this poor performance was repeated the next day, and the score of bull 2 also dropped precipitously (30% success rate). During the final experimental session, which repeated the initial task, bull 2 reached the success criterion without problems. The Mantel-Haenszel test proved that the continuous decrease in the rate of success in the comparison of 36-cm disk with the 9-cm disk to the rate of success in the comparison of the 36-cm disk with the 18-cm disk (Table 2) was significant.

Bull 3 performed well during the first trial and achieved an 80% success rate when the position of the 36-cm disk was altered at random (Figure 4). Discrimination between the 9- and 36-cm disks was no problem, and the bull reached 75% success rate. However, bull 3 could not discriminate between the 18- and 36-cm disks, and his score dropped to 30%. Reconfronted with the 36-cm disk alone and alteration of the position after two correct decisions as a final test, bull 3 scored 55% on the same day in the afternoon. In a further session on the next day, the position of 36-cm disk was altered at random, and bull 3 confirmed his ability to recognize the 36-cm disk (85% success rate). The Mantel-Haenszel test proved that the continuous decrease in the rate of success in the comparison of the 36-cm disk with the 9-cm disk to the rate of success in the comparison of the 36-cm disk with the 18-cm disk (Table 2) was significant.

Bull 4 performed very well (95% success rate) at the beginning of the experiment when he had to recognize the bucket with the 36-cm disk above it (Figure 4). Because of our experiences with the first three bulls, the fourth bull was tested for discrimination between the 36- and 18-cm disks before he was tested with the 9- or 27-cm disk. Bull 4 solved this task and reached the 70% success criterion. When tested for his ability to discriminate between the 36-and 27-cm disks, his score dropped to a level only slightly above chance. During the final session, which retested the initial task, bull 4 achieved a 95% success rate. The Mantel-Haenszel test proved that the

TABLE 2. Discrimination between disks of different size.[1,2]

Disk size[3]	Bull 1	Bull 2	Bull 3	Bull 4
No disk				
no./no.	16/20	15/20	16/20	19/20
%	80	75	80	95
9 cm				
no./no.	14/20	15/20	15/20	...
%	70	75	75	...
18 cm				
no./no.	30/60	18/40	6/20	14/20
%	50	45	30	70
27 cm				
no./no.	...	...	...	11/20
%	...	...	...	55
χ^2	6.445	6.060	10.400	8.195
$P <$	0.011	0.014	0.001	0.004

[1]The Mantel-Haenszel test with 1 df was used to determine whether the success rate decreased continuously as the size of the alternative disk increased and thus comes closer to the 36-cm disk.

[2]Significant at the $P < 0.05$ for bulls 1 and 2 or $P < 0.01$ for bulls 3 and 4.

[3]Disks discriminated from the 36-cm disk.

continuous decrease in the rate of success in the comparison of the 36-cm disk with the 18-cm disk to the rate of success in the comparison of the 36-cm disk with the 27-cm disk (Table 2) was significant.

Observations on Behavior During Experimentation

It was interesting to note the distance from the buckets at which the bulls decided to pursue the correct choice during their approach. At the beginning of the experiments, the bulls came very close to a bucket (<1 m) and then moved their heads and bodies laterally to see with one eye whether a disk was present or not. If not, bulls chose the other bucket. When bulls had become accustomed to the test, they made the decision 2 or 3 m away from the buckets (Figure 2). In these cases, the head was lifted and positioned straight forward. At the same time, the eyes and ears were oriented toward the wall with the buckets. In general, there was no hesitation during the approach, which meant that a decision had been made while walking.

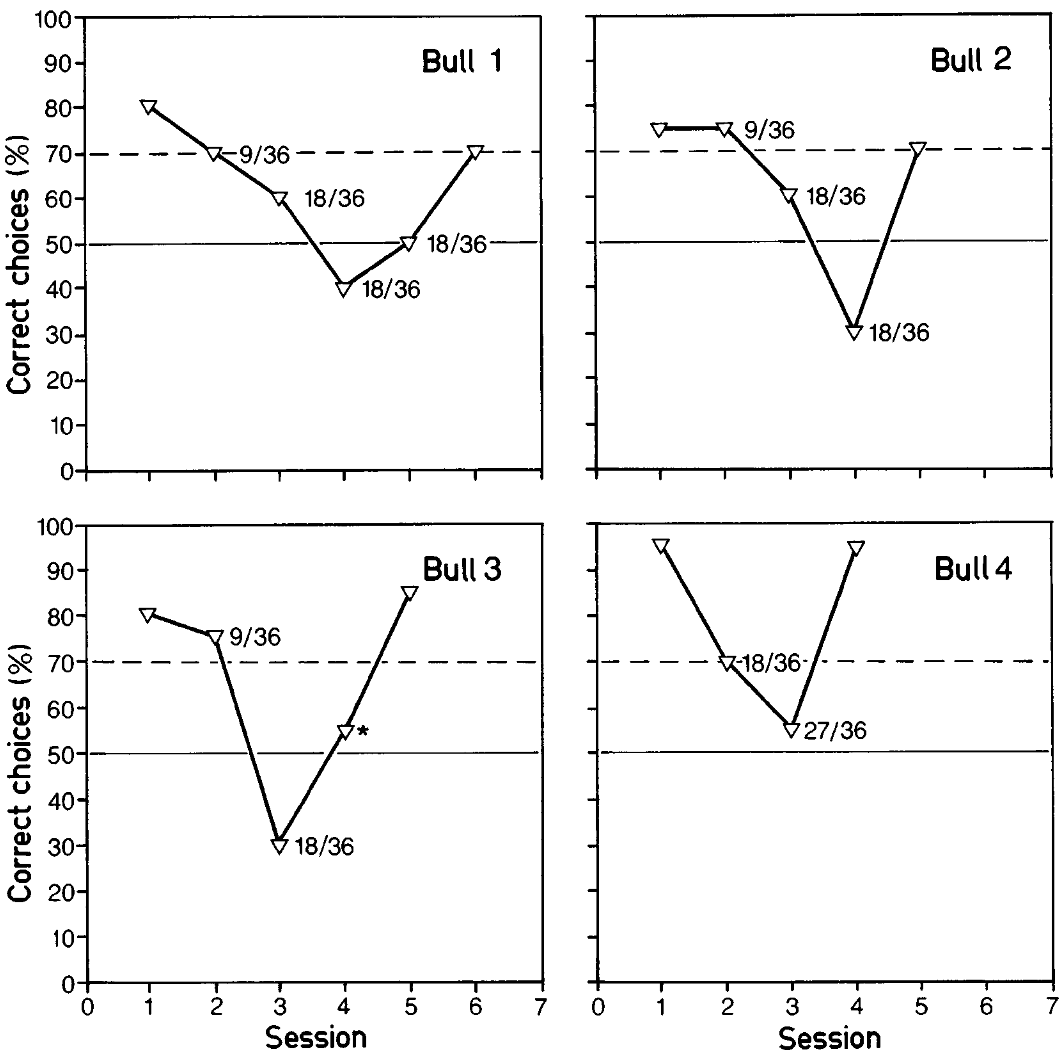

Figure 4. Learning curves of the discrimination experiments. Each session included 20 trials. The 50% line indicates the chance level; the dashed line at 70% indicates the success criterion. At the points labeled 9/36, 18/36, and 27/36, the bull had to discriminate between the correct 36-cm disk above one bucket and the 9-, 18-, or 27-cm disks, respectively, which were positioned over the wrong buckets. The position of the correct stimulus was altered at random. The first session in this figure corresponds to the last session shown in Figure 3. The last sessions in this figure were simple tasks of recognizing the bucket with a 36-cm disk, as in the original tests. The position of the disk was altered at random. For bull 3, it was necessary to revert to the original task twice (4th and 5th session). In the fourth session, denoted by an asterisk, the position of the single 36-cm disk was altered after two correct choices; in the fifth session, the disk was altered at random.

The temperament of the individual bulls was different. In general, however, bulls were sensitive and easily irritated. Disposition might influence the results. A bull that was able to decide correctly at a 90% success rate might quickly lose concentration during the next session, and his score might drop to 70% or lower. Generally, the bulls took more time to make decisions when difficulties were observed, such as when bulls stopped walking, looked at the experimental wall, looked at the researcher, or did nothing for a long period before pursuing the left or right bucket. Bulls that failed to solve the discrimination test, although they tried, did not continue to cooperate as before (bulls 1 and 3). These bulls hesitated while approaching the buckets, and they displayed no interest in the pellets. Several sessions and a great deal of patience were needed to reactivate them for further experimentation.

DISCUSSION

The ideal situation for performing experiments such as those presented here involves the use of a freely moving bull alone in the room where the bull is confronted with a task, but these conditions could not be established because of bull temperament; therefore, we cannot exclude the possibility that the bulls were influenced by the researcher. However, stimulus-related learning is obvious. Thus, we think that the design was acceptable, at least for adult bulls, which so far have not been investigated with respect to sensory and learning abilities using tests of experimental psychology.

Schaeffer and Sikes (18) studied visually guided discrimination learning in Holstein-Friesian calves. They used a Y-shaped maze and offered either black or white buckets or small or large buckets. After four sessions with 10 trials each, the calves reached at least a 90% success rate. Baldwin (2), who studied shape discrimination by sheep and calves, reported similar results. In that experiment, the animals learned very quickly and reached high percentages of correct choices.

Compared with calves, adult bulls learned very slowly and reached lower scores; a 90% success rate or higher was found only occasionally. Slower learning in older cattle than in younger cattle was also observed by Kovalcik and Kovalcik (10), who investigated learning ability and memory of 15-mo old primiparous heifers and cows. These differences might result, in part because the calves were deprived of feed at the beginning of the tests. However, we propose that differences in stage of growth and disposition between young calves and adult bulls were the primary reasons for the differences in performance. Calves are attracted by new things and demonstrate active playing behavior (13). Adult cattle, and particularly adult bulls, hardly play, and their interest in the environment seems to be limited. Perturbations of the daily routine upsets bulls, and some of them need many days to calm down. One might conclude from this behavior that novelty, as such, is not attractive to bulls. The low success scores of the bulls might have been due to this factor and not necessarily due to a cognitive deficit. Bulls can reach high scores (bull 4 in these experiments). However, the demonstration of this ability might be related to the type of reward. Spanish fighting bulls, which are defending themselves, are said to learn within a short time not to attack the muleta but to attack the matador. This behavior has led to the rule that a bullfight must be finished within 20 min (11). While being lead by a researcher, one dairy bull was suddenly startled by a loud noise and plunged away. The bull learned from this single event that he was stronger than the researcher, and, from then on, the bull could only be handled by other persons. Such opportunistic learning indicates a remarkable learning capacity in cases in which a bull senses an advantage. The low interest of adult dairy bulls in learning that was occasionally encountered in our experiments might falsely suggest a reduced learning capacity.

Very different influences on learning behavior were discussed by Arave et al. (1). They reported that male calves learned more slowly than female calves, that the type of housing played a role in learning, and that there were genetic differences in learning (i.e., the offspring of some sires learned better than those of others). These observations cannot be compared with ours.

Shape discrimination experiments demonstrated that bulls perceive objects that are smaller than 36 cm in diameter (2). The ability of the bull to discriminate means that he can visualize objects that are small in comparison to his own size. Whether this ability is integrated in social, sexual, nutritional, or retreat behavior can only be speculated. Distinguishing between the 36- and 18-cm disks or larger disks obviously was very difficult, particularly for bull 3, and only one bull (bull 4) managed to differentiate betwen disks. This result might indicate that objects <36 cm are too small to permit discrimination or that bulls need at least a fourfold difference in area to detect size differences. Using a 20-cm disk at the beginning of the experiments might influence the decision of bulls 1, 2, and 4 because the 18-cm disk was only slightly smaller. However, this effect does not seem probable, because the change from the 20-cm to the 36-cm disk was not noticed by the bulls in the first experiment. Additionally, bull 3 failed to discriminate between the 36- and 18-cm disks even though he had not been confronted with the 20-cm disk.

All four bulls recalled the first task after a series of discrimination experiments was finished, which indicated that bulls have the ability to remember learned tasks. In calves, evidence exists that such memory might last for long periods. Franz et al. (4) reported that calves remembered special tasks for >500 d.

How the bulls used their vision in solving the problem we posed was interesting. At the beginning of the experiments, the bulls approached the buckets at a very close range (<1 m), moved their heads to the side, and seemed to look laterally with one eye to see whether a disk was positioned above the bucket or not. The monocular lateral visual field was used. Later, when the bulls were more accustomed to the tests, they fixed their eyes on the buckets from a distance of 2 m before deciding to walk toward the right or left bucket. Thus, the binocular frontal visual field was used.

For chickens and pigeons, which have two fovea-like differentiations in their retinas, the question was asked whether lateral or frontal visual fields were used for different purposes (6). The binocular field was preferred primarily to solve spatial problems. The retinas of cattle are somewhat similar to those of pigeons in that they have a fovea-like central area and a visual streak (8). The latter is thought to enhance the visual acuity in the lateral visual field and might be compared with the nasal central area of the retina of the pigeon.

Our observations indicated that, at the very beginning of the experiments, the bulls separated spatial orientation from the problem of recognizing the correct bucket. They went to one bucket using spatial orientation ability and, after arriving, determined whether they were on the correct side. Spatial orientation was facilitated by a binocular visual field, and recognition of the black disk above the bucket was accomplished with the lateral visual field. When the bulls were more accustomed to the experiments, they combined spatial orientation with the identification of the correct side. Thus, both determinations were made with the binocular field.

The use of either the frontal or the lateral visual field seems to reflect the mental disposition of the bull. If the bulls seemed insecure and less self-confident, as was evidenced by their hesitation at the beginning of the experiments, the lateral visual field was preferred. If the bulls were familiar with their task and acted self-confidently (i.e., without hesitation), the binocular field was preferred to optimize their approach. This tendency coincides partly with the theory of Hughes (8), which suggests that ungulates have very large lateral visual fields for early detection of predators. In other words, the lateral field is used in situations in which the animals are threatened, anxious, or alarmed.

This paper presented some initial insights into the vision and learning of adult dairy bulls. That these bulls oriented visually very well and that they could learn and retain learning in memory was quite evident. The use of these abilities obviously depended very much on the disposition of the individual bull, which should be considered when researchers deal with bulls. However, we are far from understanding how a bull sees the world. We do not know, for example, how large the monocular and binocular fields of vision are, if visual acuity is different in these fields, or whether bulls are near-sighted or far-sighted.

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