Studies on the Visual Acuity of Pigs Using Shape Discrimination Learning

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Abstract The objective of this study was to determine the visual acuity of pigs. Six pigs were trained to discriminate between a Landolt ring and an ordinary ring of equal size associated with feed. The left and right positions of the 2 targets were shifted according to the Gellermann series. After the pigs were fully trained, their visual acuity was determined by changing the size of the rings or the distance from the target. The pigs were subjected daily to 1 or 2 sessions which consisted of 30 trials each. The criterion of successful discrimination was 3 consecutive sessions with more than 21 correct choices ($P < 0.05$, Chi-square test). Two castrated pigs were not able to learn the experimental procedure. The best scores of visual acuity in the 4 female pigs were 0.017, 0.034, 0.035 and 0.07.

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Key words : Pigs, Visual acuity, Discrimination learning, Operant conditioning

It is important to understand the function of sense organs in farm animals and thereby improve management. In recent years, some reports dealing with the application of the sensory and learning ability of animals to their management have been published. For example, Entsu *et al.*⁵⁾ studied the improvement of methods for tending cattle by conditioned sound. Manda *et al.*¹⁴⁾ investigated the response of cattle to variously colored electric fences in order to apply sensory capability to the management of grazing animals. Sheep have also been able to discriminate between different colors and have been expected to utilize this ability to control their behavior^{21,22)}. Visual acuity of ruminants was also studied and reported that the score for Japanese Black cattle and Holstein cows was between 0.04-0.08^{7,15)}. We showed that the visual acuity

score of sheep was between 0.085-0.19²³⁾. On the other hand, studies on the visual sense of pigs were very few. Color vision of pigs and wild boars was reported by Tanida *et al.*²⁴⁾ and Eguchi *et al.*⁴⁾, but the visual acuity of pigs has not been studied yet.

The objective of this experiment was to study the visual acuity of pigs by shape discrimination learning.

Materials and Methods

Three Large White female pigs (Fig 1-3 : 2 months old) and 3 crossbred (Large White × Duroc) pigs, 1 female (Fig 4 : 3 months old) and 2 castrated male (Fig 5, 6 : 3 months old), were used. The pigs were kept in individual pens and provided with only 50% of the nutrient requirements according to the Japanese Feeding Standard for Swine¹³⁾ of formula feed (CP

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15.5%, TDN 77%) at 17:00 in order to ensure sufficient feeding motivation. Water was available *ad lib.* in the pen.

The experimental apparatus is shown in Fig. 1. A Landolt ring and an ordinary ring of equal size were the negative and positive visual targets, respectively. The ring was black on a white background and covered with a clear board of acrylic resin. The targets were hung on the wall above each switch. When the switch below the positive target was pressed, 5 pieces of small cookies were delivered. The visual targets were illuminated by halogen lamps. Light intensity on the visual targets was 500–550 lux during the discrimination training and testing.

At first, the pigs were habituated to the experimental apparatus and learned the association between the switch and the reward (Training 1). The next training was conducted by using only an ordinary ring (Training 2). One training session consisting of 30 trials was done daily, and finished when the pigs completed 3 consecutive sessions with more than 21 correct choices ($P < 0.05$, Chi-square test)²⁰. Pig 5 and Pig 6 were very disturbed in the experimental apparatus even in training 1 and were not able to reach the criterion in training 2. Therefore, these two pigs were excluded from the experiment. In the following training (Training 3), the pigs were trained to discriminate between a Landolt ring (Pig 1 and Pig 2: 318 mm in overall diameter with 64 mm ring and gap widths; Pig 3 and Pig 4: 321 mm and 64 mm, respectively) and an ordinary ring of equal size at a distance of 3.6 m (Pig 1 and Pig 2) or 3.0 m (Pig 3 and Pig 4), which corresponds to a visual acuity score of 0.017 (Pig 1 and Pig 2) or 0.014 (Pig 3 and Pig 4).

After the pigs were fully trained, their visual acuity was determined by changing the size of the rings or the distance from the target^{12,18}. The pigs were subjected daily to 1 or 2 sessions consisting of 30 trials. In each trial, the door of the waiting box was opened, and the pig

went into one of the choice alleys. The pig returned to the waiting box after pushing the switch. The choice was recorded when the pig put its foot into either the left or right alley. There was no case that the pig did not enter the alleys. Each session started at 09:00 or 14:00 and ended within 1 h. Each trial was conducted at intervals of 15 s. The arrangement of the targets in each trial was changed according to the Gellermann series⁹ during the interval time. The criterion of successful discrimination in each visual acuity score test was 3 consecutive sessions with more than 21 correct choices in 30 trials until the 15th session²⁴.

Results

During the second training period using only an ordinary ring, it took 4–12 sessions for the pigs to learn the relationship between a positive target and a reward. In the subsequent discrimination training between the Landolt and ordinary rings, the pigs performed very different responses. Pig 1 reached the learning criterion after the 8th session. In Pig 2, however, the correct choices were more than 21 trials in a few sessions but no 3 sessions were consecutive until the 74th session. Therefore, the length of the choice alleys was shortened to 1.8 m (visual acuity score: 0.0085). Then, Pig 2 reached the learning criterion after the 14th session. As Pig 3 and Pig 4 were not able to reach the criterion during 15 sessions, the gap of Landolt ring was enlarged to double widths. After Pig 3 and Pig 4 were fully trained by the modified rings during 8 (Pig 3) or 26 (Pig 4) sessions, both pigs were tested again using the original rings and were able to discriminate them in the first 3 sessions.

The results of the discrimination test for Pig 1 and Pig 2 are shown in Table 1. Pig 1 reached the criterion of successful discrimination by the 8th session with a visual acuity score of 0.017–0.03. In the case of 0.035, the correct responses amounted to more than 21 trials (70%) in only the 13th session, but there

Table 1. Rate of correct choices of Pig 1 and Pig 2 in varying visual acuity scores (%)¹

VAS ²	Session number																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	(16)	(17)	(18)
Pig 1																		
0.017	<u>76.7</u>	53.3	63.3	56.7	66.7	<u>73.3</u>	<u>73.3</u>	<u>76.7</u>										
0.02	<u>76.7</u>	<u>76.7</u>	<u>76.7</u>															
0.025	66.7	<u>86.7</u>	<u>76.7</u>	<u>76.7</u>														
0.03	53.3	63.3	<u>73.3</u>	<u>76.7</u>	<u>76.7</u>													
0.035 ³	43.3	50.0	60.0	40.0	60.0	63.3	53.3	43.3	66.7	56.7	63.3	63.3	<u>73.3</u>	50.0	66.7	<u>76.7</u>	<u>70.0</u>	<u>70.0</u>
0.04	50.0	63.3	66.7	<u>73.3</u>	66.7	66.7	53.3	60.0	66.7	60.0	50.0	60.0	46.7	46.7	56.7			
Pig 2																		
0.0085	53.3	46.7	53.3	50.0	56.7	50.0	56.7	53.3	50.0	66.7	60.0	<u>80.0</u>	<u>86.7</u>	<u>80.0</u>				
0.01	<u>90.0</u>	<u>93.3</u>	<u>93.3</u>															
0.0125	<u>86.7</u>	66.7	<u>83.3</u>	60.0	<u>73.3</u>	63.3	<u>83.3</u>	<u>70.0</u>	<u>80.0</u>									
0.015	<u>80.0</u>	56.7	56.7	66.7	<u>80.0</u>	<u>83.3</u>	60.0	63.3	<u>76.7</u>	<u>76.7</u>	<u>93.3</u>							
0.016 ⁴	56.7	46.7	66.7	63.3	60.0	73.3	63.3	56.7	53.3	56.7	36.7	<u>73.3</u>	66.7	<u>70.0</u>	<u>70.0</u>	<u>70.0</u>		
0.017	66.7	<u>70.0</u>	66.7	53.3	63.3	60.0	<u>73.3</u>	<u>70.0</u>	<u>70.0</u>									
0.018	60.0	63.3	46.7	66.7	53.3	56.7	53.3	63.3	56.7	60.0	46.7	56.7	40.0	53.3	60.0			

¹ Underlined values are sessions with above 70% correct choices.² Visual acuity score.³ Three more sessions were conducted because there were 8 consecutive correct choices ($P < 0.05$) in the 15th session.⁴ One more session was conducted because the correct choices in both 14th and 15th sessions were above 70%.

were 8 consecutive correct choices ($P < 0.05$, Grant Trend test)¹⁰ in the 15th session. Therefore, the test was continued and the correct choices in the following 3 sessions were above 70%. For 0.04, the responses were correct in more than 21 trials in only the 4th session and no 3 sessions were consecutive. Therefore, the score of visual acuity for Pig 1 was determined as 0.035. In the visual acuity score of 0.035, the discrimination distance was 3.6 m, and the sizes of the Landolt ring were 154 mm in overall diameter, and 31 mm for the widths of the ring itself and the square gap, respectively.

As the visual acuity of Pig 2 seemed to be relatively weak according to the result of training, the animal was tested from low score and increased in the score step by step. It required 14 sessions to reach the criterion of successful discrimination in first case of 0.0085. In the next case of 0.01, the pig reached the criterion

after the first 3 sessions. For the scores of 0.0125 and 0.015, it took 9 and 11 sessions to reach the criterion, respectively. For 0.016, as there were 21 correct responses in both 14th and 15th sessions, one more session was conducted, and the correct responses in the session were 70%. In the case of 0.017, it took 9 sessions. However, the pig was not able to reach the criterion in the case of visual acuity score of 0.018. Therefore, the score of visual acuity for Pig 2 was determined as 0.017. In the visual acuity score of 0.017, the discrimination distance was 1.8 m, and the sizes of the Landolt ring were 159 mm in overall diameter, and 32 mm for the widths of the ring itself and the square gap, respectively.

The results of the discrimination test for Pig 3 and Pig 4 are shown in Table 2. Pig 3 reached the criterion of successful discrimination after the first 3 sessions in the test for 0.014,

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Table 2. Rate of correct choices of Pig 3 and Pig 4 in varying visual acuity scores (%)¹

VAS ²	Session number														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Pig 3															
0.014	<u>73.3</u>	<u>73.3</u>	<u>73.3</u>												
0.02	66.7	<u>73.3</u>	<u>70.0</u>	<u>70.0</u>											
0.024	<u>73.3</u>	<u>80.0</u>	60.0	<u>70.0</u>	<u>70.0</u>	<u>70.0</u>									
0.03	66.7	<u>70.0</u>	60.0	50.0	60.0	63.3	<u>76.7</u>	<u>70.0</u>	<u>70.0</u>						
0.034	66.7	63.3	63.3	<u>73.3</u>	<u>70.0</u>	<u>86.7</u>									
0.04	66.7	56.7	<u>70.0</u>	63.3	<u>80.0</u>	<u>70.0</u>	50.0	66.7	<u>73.3</u>	<u>83.3</u>	<u>70.0</u>				
0.05	<u>73.3</u>	53.3	<u>76.7</u>	<u>76.7</u>	<u>70.0</u>										
0.06	<u>73.3</u>	56.7	<u>80.0</u>	<u>70.0</u>	<u>76.7</u>										
0.07	<u>73.3</u>	66.7	60.0	<u>86.7</u>	<u>73.3</u>	63.3	56.7	66.7	<u>73.3</u>	<u>70.0</u>	<u>70.0</u>				
0.08	<u>76.7</u>	63.3	60.0	56.7	60.0	63.3	56.7	63.3	<u>70.0</u>	46.7	<u>73.3</u>	53.3	53.3	46.7	53.3
Pig 4															
0.014	<u>76.7</u>	<u>86.7</u>	<u>70.0</u>												
0.02	66.7	<u>73.3</u>	<u>83.3</u>	<u>83.3</u>											
0.024	<u>86.7</u>	<u>73.3</u>	<u>70.0</u>												
0.03	63.3	63.3	60.0	46.7	66.7	66.7	66.7	63.3	63.3	56.7	63.3	<u>70.0</u>	<u>80.0</u>	<u>80.0</u>	
0.032	56.7	<u>80.0</u>	<u>80.0</u>	<u>76.7</u>											
0.034	<u>80.0</u>	<u>70.0</u>	<u>70.0</u>												
0.036	56.7	66.7	<u>73.3</u>	53.3	66.7	60.0	56.7	60.0	<u>73.3</u>	60.0	50.0	63.3	<u>70.0</u>	<u>73.3</u>	63.3

¹ Underlined values are sessions with above 70% correct choices.

² Visual acuity score.

and the number of sessions increased gradually up to the visual acuity score of 0.04 (except for 0.034 which took 6 sessions). However, in the cases of 0.05 and 0.06, it took only 5 sessions to reach the criterion. In the subsequent case of 0.07, the pig took 11 sessions. For 0.08, the responses were correct in more than 21 trials in 3 of 15 sessions, but no 3 sessions were consecutive. Therefore, the visual acuity score for Pig 3 was determined as 0.07. For the visual acuity score of 0.07 at a fixed distance of 3.0 m, the sizes of the Landolt ring were 64 mm in overall diameter, and 13 mm for the widths of the ring itself and the square gap.

Pig 4 reached the criterion of successful discrimination after less than the first 4 sessions in all tests, up to the visual acuity score of 0.024. In the next case of 0.03, it took 14 sessions. Then, Pig 4 was tested by increasing a score step by step as like as Pig 2. However, it took

only 4 and 3 sessions to reach the criterion in the cases of 0.032 and 0.034, respectively. In the case of 0.036, the responses were correct in more than 21 trials in 4 of 15 sessions, but no 3 sessions were consecutive. The differences between the Landolt rings for 0.034 and 0.036 in the size of diameter and gap were only 7 mm and 1 mm, respectively. Therefore, the pig was tested in the score of 0.04 by way of precaution, but there was no session with more than 21 correct choices. Then, the visual acuity score for Pig 4 was determined as 0.034. For the visual acuity score of 0.034 at a fixed distance of 3.0 m, the sizes of the Landolt ring were 132 mm in overall diameter, and 26 mm for the widths of the ring itself and the square gap.

Discussion

The visual field of pigs was measured by Prince¹⁶⁾. The report showed that the mean

Fig. 1. Experimental room design (left) and the front of the room (right). CP, choice point; WB, waiting box; VT, visual target (left, ordinary ring as a positive stimulus; right, landolt ring as a negative stimulus); SW, switch; FT, feed trough.

binocular field just at eye level was 30–50°. As the experimental apparatus of the present study (Fig. 1) was made by referring to Prince's data, the size and arrangement of visual targets were considered to be suitable for discrimination learning in pigs.

Landolt and ordinary rings were used in this study based on the ruminants' visual acuity reports^{7,23}. However, it was very difficult for some pigs to learn the difference between those rings. It was effective to enlarge the gap of Landolt ring for those pigs to solve that problem. Therefore, some other targets (e.g. a grated vs. plain gray target, etc.) might be more suitable for pigs.

Four female and two castrated male pigs were used in this study, but the behavior of castrated males allowed no training. Rosengren¹⁷ reported the same tendency on a male dog which was trained to discriminate

among different colors. Male animals might be commonly hard to train the operant conditioning, therefore additional research will be necessary to clarify the differences of trainability and learning ability by sex.

The visual acuity of mammals except for primates is not well developed generally¹¹. Entsu⁶ trained cattle to learn shape discrimination in order to determine their visual acuity, and reported that the score for Japanese Black cattle was between 0.045–0.083⁷. Manda *et al.*¹⁵ also reported similar results for Holstein cows and Japanese Black cattle. We showed that the ability of sheep to resolve visual details is almost the same as in cattle, and seems relatively limited in comparison with humans²³. The results of the present study suggests that the visual acuity of pigs is also almost the same as the ruminant, or slightly poorer.

On the other hand, it has been reported that the bighorn sheep can spot moving objects up to a distance of 1000 m⁸⁾. The eye placement in the skull varies among species of mammals. This means that each species has its own evolutionary visual field and acuity. It might be more important for ruminant and also pigs to find faraway predators rather than to resolve lines and shapes.

In addition, it is known that visual resolving power in humans decreases under low light intensity¹²⁾, and that the visual acuity of one eye is different from that of both eyes¹⁹⁾. These problems in pigs should also be studied.

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図形識別学習法によるブタの視力測定

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本研究は、ブタの視力について、ヒトにおける視力検査の基準を用いて検討した。6頭の育成豚（雌4頭、去勢2頭）を供試し、試視力用のランドルト環と、その切れ目をなくした円図形とを用い、それぞれ負および正刺激として飼料と連合学習させた。二者択一式のY字型迷路を自作し、図形の大きさまたは図形までの距離を変化させ、両図形の識別の可否から視力を判定した。左右の図形の交換は、ゲラーマン系列の乱数表に従って行った。その結果、去勢豚2頭は学習が成立せず、視力測定ができなかったが、雌豚4頭の視力値は、0.017～0.07の範囲にあった。

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