

**The influence of birth weight
& coping style on
visual discrimination learning
in pigs**



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The influence of birth weight & coping style on visual discrimination learning in pigs

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Abstract

To improve the housing environment and treatment of the commercially bred pig, it is necessary to know as much as possible about this species, for example about cognition. Studying cognition and the factors influencing learning and memory therefore can help to improve welfare directly by modifying their housing conditions, and indirectly by influencing peoples' thoughts about pigs' welfare and their obligations towards these animals.

Low birth weight is known to influence cognition negatively in human children. A lot of domestic piglets are also born with a low birth weight, due to the selection for large litters. Therefore, we investigated the influence of birth weight on cognition in piglets.

Coping style - a set of behavioural and physiological stress responses that is characteristic to certain animals - may also influence learning. Coping style in pigs may be predicted by a back test, in which piglets are put on their back for 60 s: animals that struggle and vocalise a lot have a proactive coping style, animals that are quieter and struggle less have a reactive coping style. Animals with a proactive coping style seem to be less flexible in their behaviour and therefore learn reversals less easily. Coping style might also be correlated with birth weight.

From studies in sheep and cows it is known that those animals can discriminate and recognize conspecifics from 2D photographs of their heads, taken at different angles. We investigated this ability in pigs.

To investigate the influence of birth weight and coping style on learning ability, we used a visual discrimination task. But first, we selected nine pairs of piglets of nine sows. Each pair consisted of one piglet with a normal birth weight and one piglet with a low birth weight. At the age of 21 days, all piglets were subjected to the back test. At the age of four weeks, piglets were housed in two adjacent pens and habituated to the visual discrimination apparatus and the experimenters. The testing period consisted of four phases: shaping, training, reversal 1 and reversal 2. During the shaping phase, one black and white stimulus was present on the left or right side of the apparatus and piglets had to learn to choose this stimulus in order to obtain a food reward. During the training phase, two black and white stimuli were present at the same time left and right, and the piglets had to choose the stimulus that had been rewarded during shaping. During the reversal, the unrewarded stimulus became rewarded. During the second reversal phase, the first rewarded stimulus was rewarded again.

To study the role of vision in recognition of conspecifics, the four piglets that scored best during the first experiment and their littermates were selected for the next experiment. Photos were made of the heads of the pigs from one pen, and the photos were manipulated in Adobe Photoshop to give them a neutral grey background. Testing occurred in the same visual discrimination apparatus and consisted of showing two different pig heads simultaneously. One of the photos was rewarded. Siblings had the same photo pair and the same photo that was rewarded.

Birth weight did not influence learning ability in the visual discrimination test, but was negatively correlated to the number of struggles in the back test. We could not test whether results of back test influenced reversal learning, because there were too few animals that learned the reversal. Number of vocalizations in the back test was positively correlated with the number of trials in the learning the shaping phase.

None of the pigs learned to discriminate between two different photos of pig heads.

Introduction

Pig welfare

Pigs were domesticated some 5000-10.000 years ago in Europe and Asia. Nowadays they live in environments very different from where their wild ancestors, the wild boars, lived ¹. Pigs, as wild boars, are social animals. Wild boars live in small groups of several females and their offspring. Other individuals may be loosely associated with this group, for example adult males during mating season. They are found in forest and scrub brush areas surrounding waterholes, in swamps and marshes. Most of the day they spend foraging with their nose rooting in the soil. They eat acorns, nuts, berries and other vegetal material. Swine and pigs use sight, hearing and smell for communication, but hearing and smell appears to be better developed than sight ². They use olfaction for individual recognition and have special pheromones that carry specific messengers. However, they use visual cues such as the position of the ears or tail, and body posture also for social communication ¹.

From observation of feral pigs it is known that pigs still have the same needs and behavioural repertoire as wild boar, although their current living environments are very different ¹. Farm animals, however, need to learn a lot of different things in their life: young weaned piglets have to learn immediately where their food is located and how the food supply mechanism works, who their pen mates are, which piglets are subordinate and which are dominant. This is in contrast to nature, where weaning process is gradually. After weaning pigs are usually transported to a fattening farm where they again have to discover and learn a lot of mechanisms. When they reached the slaughter weight, they will be transported to the slaughterhouse and again learning is needed.

Efficient learning will directly lead to greater productivity if it leads to more food intake, but it can also improve welfare ². This is because animals function best in intermediate predictable and controllable environments: without short lasting stress and challenges they may suffer from boredom, but if the environment is not controllable and predictable at all, the animal may get stressed. An animal perceives its environment as controllable if it understands how it works and how the environment can be changed. Animals only reach that by learning ³. That is why more knowledge is needed about which factors influence learning ability in farm animals, in this case in pigs.

Knowledge about the level of cognition (for example learning abilities, social recognition) of animal species can also lead to more awareness and concern about animals and their welfare, and can be used in decisions about obligations to animals and to design cognitive enrichment for a specific species ⁴.

It is also important to gain insight in how selection in intensive (but also organic) pig industry towards a bigger litter size influences other factors, like learning. Besides looking at welfare, low birth weight pigs might also serve as a model for low birth weight human babies.

In this thesis we wanted to gain more knowledge about pigs' (visual) learning abilities, factors that may influence learning and the role of sight in social recognition in pigs. To this end, we performed a series of experiments: we looked at the difference in visual learning ability between low and normal birth weight piglets and between piglets with different coping styles. Further, we investigated discrimination and recognition of conspecifics in pigs by means of 2D photos.

Birth weight

One of the factors that may influence learning abilities and welfare is birth weight. Research in humans has shown that birth weight and cognitive performance are correlated. Some children with low birth weight suffer from severe developmental disabilities, such as cerebral palsy or mental retardation (10-15 % in Very Low Birth Weight children; VLBW and 20-25% in Extreme Low Birth Weight children; ELBW) ⁵. When considering also less severe problems, 30-65% of ELBW children has learning problems at school or need special education ⁵.

Children with a low birth weight who were born pre-term have often compromised abilities to learn mathematics, reading, writing and spelling compared to children that were born with a normal birth weight and full term. This difference exists even if only looking at the children who score within the normal IQ-range (85 or above). Most children born with a low birth weight have an IQ within the normal range, but there is a larger group compared with normal birth weight children with an IQ lower than 85 points ⁵.

In a study by Leitner *et al.* (2005) ⁶, the spatial learning abilities of normal children and children with intrauterine growth retardation (IUGR, another description of low birth weight, in which SGA can be a readout parameter) were investigated using a radial arm maze. IUGR children performed less well than normal children in this task.

In monkeys (*Macaca nemestrina*) it is also shown that low birth weight babies have lower cognitive abilities, concerning a visual recognition task in Gunderson *et al.* (1989) ⁷.

A low birth weight may be associated with one of several factors: smoking during pregnancy, multiple pregnancies, heavy alcohol consumption or intrauterine infections ⁸. However, one of the most common causes is placental insufficiency, which means that nutrient and oxygen transport through the placenta is poor ⁹. The learning problems associated with a low birth

weight are caused by brain injuries, which are caused by the oxygen deprivation due to insufficient placental transfer of oxygen ⁵.

Martinussen *et al.* (2009) ¹⁰ found that VLBW children have reduced volumes of thalamus and cerebral white matter. Small for gestational age (SGA) children have smaller brains and proportionally smaller regional brain volumes. The volumes were found to be good predictors of cognitive and perceptual functions.

In conclusion, there is ample evidence for the notion that birth weight is related to cognitive performance in humans. However, there is also scientific evidence that contradicts this conclusion. In a study by Westwood *et al.* (1983)⁸ children with other complications during pregnancy or birth that may influence learning ability except for a low birth were excluded. These were problems like neonatal asphyxia, prematurity and intrauterine growth retardation. Cognitive abilities in these 'normal' low birth weight children were slightly lower than in normal birth weight children, but well within the normal range ⁸.

A considerable proportion of domestic piglets is also born with a very low birth weight. This is due to increased litter size in response to genetic selection in the intensive pig industry ¹¹. In wild boar litter size is about five to seven piglets per nest ¹² and in domestic meat pigs the average number of piglets per nest is thirteen ¹³. In the organic pig industry the litter size is even slightly higher: this may be due to weaning at a later age. By increasing the lactation period, the sow has more time to regain a positive energy balance. This balance influences the number of ovulations and the survival of the egg cells in the uterus (veterinarian UU Bas Swildens, pers. comm).

In a study by Milligan *et al.* (2002) ¹³ it was found that piglets with birth weights well below the mean of the litter have a greater risk to die. These piglets have a low survival in large litters and in litters from sows with at least five previous parities. The birth weights of most litters show a negatively skewed distribution, with most of the piglets well below the mean birth weight. Piglet birth weight has also an effect on locomotion ¹⁴: low birth weight piglets confronted with a rubber ball needed more time to touch the ball and to move the ball compared with normal birth weight piglets.

Coping style

Learning, and especially reversal learning, can also be influenced by other factors than cognitive abilities. Reversals in a learning task can represent changing factors in a natural environment. It seems that some animals have more flexible behaviour and thus learn reversals more easily than others. This may depend, among other factors, on the coping style of the animal. A coping style is a set of behavioural and physiological stress responses

that are consistent over time and which are characteristic to certain individuals. Coping styles are shaped by evolution and are adaptive response patterns to challenges in the natural environment. Each individual seems to adopt a certain coping style and the different styles are present in all kinds of animals: from great tits ¹⁵ to mice ¹⁶ and rainbow trout ¹⁷. Coping styles are strongly heritable ¹⁶.

Coping styles were first discovered in mice. Male mice confronted with an intruder react in two ways: they can attack rapidly or flight ('proactive coping style') or stay immobile ('reactive coping style'). Proactive copers try to remove the source of stress actively or to run away from the source of stress. Reactive copers try to reduce the emotional impact of the stress by staying immobile; this behaviour increases the chance that the aggressive intruder will calm down and will stop fighting ¹⁶.

Coping styles include behavioural characteristics like aggression ^{18,19} boldness¹⁵, exploratory behaviour ¹⁹ and behavioural flexibility; animals with a proactive coping style are more aggressive, explore a new environment less well and therefore adjust their behaviour less to cues from the environment (behavioural routine forming) ^{18,16}. The success of the two alternative styles depends on the environment. Proactive male mice, with more behavioural routine forming, will be favoured in a stable environment. Reactive males have an advantage in a migratory (changing) environment because they explore the new environment better, adjust their behaviour and thus have a greater chance to establish a new territory there ¹⁶. Behavioural flexibility can be measured in learning tasks. Benus *et al.* (1990) ¹⁸ found that aggressive males, when confronted with a reversal in a Y-maze, made significantly more errors than low aggressive males. The number of errors is an indicator for the degree of routine formation and thus of behavioural flexibility.

Coping mechanisms are believed to play a role in health and disease susceptibility differences between animals ¹⁶. It seems that animals with a proactive coping style are more susceptible to hypertension and stress ²⁰. Therefore, researchers have paid attention to the individual vulnerability to stress-related diseases and coping mechanisms.

There is ample evidence that pigs also adopt different coping styles. Coping style may be predicted from a test early in life, the so-called back test ²¹. In this test, the piglet is placed on its back for 60 seconds. The number of struggles with at least the hind legs and the number of vocalizations are scored during this period. Piglets with more than two struggles are defined as high resistant (HR; proactive coping style) and piglets with less than two struggles are defined as low resistant (LR; reactive coping style). Piglets with exactly two struggles are placed in an intermediate group or defined as HR or LR dependent on the number of vocalizations (Dr. Ir. Liesbeth Bolhuis, Adaptation Physiology Group, Wageningen University, pers. comm.). The outcome of the back test seems to correlate with other

behavioural characteristics, such as aggression. This relationship is consistent over time ²¹. ²². However, some studies failed to find a correlation between outcomes of the back test and reactions later in life to environmental challenges, such as a confrontation with a novel pig or human ^{23, 24, 25, 26}.

Bolhuis *et al.* (2004) discovered that LR and HR pigs perform equally well when acquiring a spatial T-maze task. However, LR pigs needed fewer trials to learn a reversal task in the T-maze than HR pigs. This indicates that HR pigs are more routine-like in their behaviour and are less flexible. This correlates with the results obtained with male mice in the study of Benus *et al.* (1990)¹⁸.

Coping styles may be correlated with birth weight. Birth weight may not only affect learning ability, as mentioned before, but also an individual's personality. Medoff-Cooper (1986) ²⁷ found that very low birth weight children were less adaptable and more 'intense' during their first 6 months. Pyhälä *et al.* (2009) ²⁸ also found differences in personality between adults born SGA and AGA (appropriate for gestational age) using various tests. SGA adults scored lower on a fun-seeking test and SGA women scored higher on behavioural inhibition.

Some observations suggest that low birth weight piglets struggle a lot when exposed to a back test compared to normal birth weight piglets and thus have a more proactive coping style (Dr. Ir. Liesbeth Bolhuis, pers. comm.). This may indicate that in pigs, birth weight is also correlated with personality.

Learning tests

To study learning ability in animals, various tests are available, for example the previously mentioned Y-maze. Another test is a visual simultaneous discrimination task. In this task, the animal has to learn that choosing a certain visual stimulus (a picture or image) is associated with receiving a reward. After learning that, two stimuli are present simultaneously and the animal has again to learn to choose the previous rewarded one. Not very many experimenters have used this type of learning test for pigs. However, Moustgaard *et al.* (2002) ²⁹ found that Göttingen minipigs were able to learn a black-white discrimination and a right-left discrimination. The discriminations seemed to be equally difficult, but in the visual modality the reversal was found to be more difficult.

Recognition

Recognition is another element of cognition and is important to form and maintain relationships in the social life of animals. Different recognition systems exist, like the

recognition of self, mates, conspecifics, kin, offspring and individuals³⁰. Individual recognition refers to a subset of recognition that occurs when one organism identifies another one, according to its unique distinctive characteristics. Individual recognition involves a mental representation of the distinctive characteristics of a specific individual. This mental representation is activated when that particular individual is perceived³¹.

Recognition can be based on several sensory modalities. Individual specific odours are used for individual recognition in ring-tailed lemur (*Lemur catta*) populations. Chemical analyses show the existence of an individual profile for the scent mark of males, thus providing a basis for individual recognition in these lemurs³². Spectacled parrotlets (*Forpus conspicillatus*) use vocalizations to recognize conspecifics³³. Various animals are able to discriminate and recognize other individuals by their faces, such as chimpanzees and Rhesus monkeys³⁴.

However, not only animals with higher cognitive abilities as monkeys and primates can recognize faces. Coulon *et al.* (2007)³⁵ discovered that cows (*Bos taurus*) are able to discriminate between 2D photos of conspecifics and photos of other species. Cows can also discriminate between individual conspecifics using only visual information when presented with live animals³⁶. In another study by Coulon *et al.* (2009)³⁷, heifers were presented with photos of familiar cows of their own breed, and unfamiliar heifers of their own breed and of other breeds. In the training phase, the heifers had to discriminate between frontal views of other heifers. In the generalization phase, the animals were confronted with other views (profile, ¾) of the cows. All heifers were able to discriminate between other heifers from their own breed in the training and generalization phase (either familiar or unfamiliar). Almost all heifers could discriminate between cows from different breeds, but needed more trials during the generalization phase.

In an experiment by Ferreira *et al.* (2004)³⁸, ewes were trained to discriminate between pairs of unknown individuals. Ewes then learned a transfer to the same pair but at a different age faster than a transfer to a novel pair of the same age (control test). Learning a discrimination of frontal views also resulted in faster learning of the profile views of the same animals compared to profile views of a novel pair. After that, the ewes were confronted with the same pair of individuals, but at a different age, and with a novel pair of the same age. They learned the discrimination of the novel pair more slowly. The ewes also learned a discrimination of frontal views of the novel pair more slowly.

This study shows that sheep form a mental representation of conspecifics in their mind and therefore can recognize individuals, otherwise they would not learn views of the same pair of individuals easier than views a novel pair.

It is also shown that sheep are better in discriminating between faces than between 'meaningless' geometric figures³⁹.

Nevertheless, photographs are different from live animals and it is discussable whether animals do see photographs as representations of live animals. It is possible that animals can perfectly discriminate between photographs of conspecifics, but see the photos as 'trifling chimeras, platonic dreams of a strange creature, at best as fictive conspecifics'⁴⁰. If animals do see 2D images as representations of real animals, they will learn to discriminate images of familiar conspecifics more easily than photos of unfamiliar individuals⁴⁰. Dasser (1987)⁴¹ demonstrated that long-tailed macaques learn to discriminate faces of familiar and unfamiliar monkeys. In a transfer test, the monkeys only matched novel slides (of other views of the face and other parts of the body) correctly, when these slides represented familiar group members.

Some experiments studied social discrimination and recognition in pigs. Mc Leman *et al.* (2004)⁴² demonstrated that pigs could discriminate between other (live) pigs using bimodal sensory cues or just one sensory modality. The pigs did not differ in learning ability according to the different sensory modalities. Ewbank & Meese (1974)⁴³ studied the role of sight in the hierarchy formation in pigs. Preventing the pigs from seeing each other by putting contact lenses on their eyes did not stop the formation of a hierarchy. However, placing 'hoods' on the pigs' faces did prevent this, but that could also be due to the covering of pheromone producing areas. So there is not yet consensus about whether pigs use visual cues for individual recognition.

Aim of the present study

The first aim of the present study was to investigate the influence of birth weight and coping style on learning ability of pigs by means of a visual discrimination task (first experiment). We chose for using a visual discrimination task because knowledge about the visual discrimination abilities of pigs is poor. Another aim was to investigate recognition of conspecifics by means of 2D photos (second experiment). The study was divided in different research questions:

- 1) *Does birth weight and/or back test scores (coping style) influence learning ability?*

To determine the coping styles of the piglets, a back test was performed at about 21 days of age and piglets were weighed at day three after birth. We performed a visual simultaneous discrimination task, involving two black and white stimuli. In the first phase of the experiment (the shaping phase), only one stimulus was present. In the

second phase (the training phase), two stimuli were present. In the third phase, a reversal was performed and in the fourth phase another reversal was done.

2) *Is there a correlation between birth weights and back test scores?*

Correlations between birth weight and back test scores were calculated.

3) *Can pigs discriminate and recognize other pigs from 2D photographs?*

In the first phase it was tested whether pigs can discriminate between two pictures of pigs in front view. In the second phase, the rewarded photo would be presented in combination with front views of different pig heads in order to investigate if pigs can discriminate between conspecifics using sight alone. We also scheduled a third phase (transfer phase) in which the front and lateral views of the rewarded pig was shown in combination with front and lateral views of different pigs. In this phase we intended to investigate whether pigs make a mental representation of the distinctive characteristics of other pigs, e.g. have a concept of the other pig in their mind. To be sure that pigs see 2D photos as representations of real pigs, we confronted one group of pigs with photos of their pen mates and the other group with the same photos. This last group had never seen the pigs on these photos.

Hypotheses

In our study, this leads to the following hypotheses and expectations:

1) *Low birth weight piglets have lower learning abilities than normal birth weight piglets*

- Piglets with a low birth weight need more trials to reach the 'criterion of learning' in the different phases (80% or more correct choices during two successive sessions) than animals with a normal birth weight.
- Piglets with a low birth weight show more often certain learning strategies (like always alternating or having a side bias) compared to normal birth weight controls. This behaviour may interfere with acquiring the task.

2) *Piglets with a proactive coping style learn reversals less well than piglets with a reactive coping style, but have further the same learning abilities:*

- The back test scores (struggling, vocalisations) and the amount of trials needed to learn a reversal, are positively correlated.

- Piglets with a reactive or proactive coping style need the same amount of trials to learn the shaping and training phase
- 3) *Birth weight and back test scores are correlated*
- Piglets with a low birth weight will have higher scores (nr. of struggles, vocalizations) in the back test compared to piglets born with a normal birth weight
- 4) *Pigs are able to discriminate between photos of unfamiliar and familiar conspecifics*
- Pigs are able to discriminate between frontal views of familiar and of unfamiliar individuals
- 5) *Pigs see 2D photos as representations of real pigs*
- Pigs need fewer trials to learn the discrimination of photos of familiar animals compared to photos of unfamiliar animals
 - During the transfer phase, pigs confronted with photos of unfamiliar pigs need more trials to learn this phase than pigs confronted with photos familiar pigs
- 6) *Pigs form a concept of other individual conspecifics and are thus capable of individual recognition using visual cues*
- If pigs form a concept of another pig in their mind, they will need fewer trials to learn the transfer phase than learning the first two phases. If they need the same amount or more trials, they probably just learned a new discrimination instead of recognizing the individual

Animals, Materials and Methods

Animals

Eighteen female piglets (nine pairs) were used in this experiment: nine animals with a normal birth weight and nine with a low birth weight. The piglets were derived from nine litters born at a commercial pig-breeding farm and were all cross-breds (Duroc x Yorkshire and Duroc x Danish landrace). Piglets' tails were docked at an age of three days. From every nest, one normal birth weight piglet and one piglet with a low birth weight was chosen. In order to find the low birth weight piglets, during two weeks all newborn piglets were weighed on day three after birth (day of birth= 0) and were earmarked. The overall standard deviation and mean of these litters and all other litters that were weighed in the course of

one year were determined (40 nests in total). Those measures were used to define low birth weight:

Low birth weight is defined as: A weight smaller than the overall mean weight of all litters in the database - at least 1x the standard deviation of this mean.

The piglet with the lowest birth weight that looked healthy enough to survive was chosen from every litter. A new mean weight per nest was then calculated after excluding all low birth weight piglets to derive a new average. The female piglet with a birth weight closest to this new mean was also chosen from every litter and served as normal weight control. Four 'stand-by' piglets were chosen, in case one of the chosen piglets would die before starting behavioural testing in the experiment.

The selected animals and the four 'stand-by' piglets were marked with different symbols per litter. Sisters were marked with the same symbol: green for the low birth weight sister and blue for the normal birth weight sister. All piglets stayed with the mother until weaning age. This differed between litters but ranged from three to four weeks. Unfortunately, one of the piglets died from pneumonia in the second week of the habituation phase of the experiment (causation not known). The experiment was continued with seventeen piglets.

Table 1. Pigs used for the photo experiment

Best performing piglet	5	8	10	12	17
Sibling	6	7	9	11	15

In the first row the five best performing pigs of the first experiment are shown, which were also used in the photo experiment. In the second row the corresponding siblings are shown, which were also tested in the photo experiment. Animal number 15 was selected instead of piglet 17's sister number 18. This was done because piglet 18 was much unmotivated at the end of the first experiment. Because only piglet 15 and 16 were available instead of number 18, we selected one of these pigs randomly.

For the photo-experiment ten gilts with an age of about six months were used. These were the same animals as used in the first experiment. The five gilts that performed best in the previous experiment and their sibling sisters were selected (Table 1). 'Best performing' means that they reached reversal 1 or 2. We chose to use also the sisters, because we wanted to investigate if not only the 'smartest' pigs could discriminate between faces. It

could be possible that pigs can discriminate better using pictures of real animals than using 'meaningless' images, as has been observed in sheep ³⁹.

Housing

After weaning the piglets were group-housed in two adjacent horse pens, adapted to house piglets. Siblings stayed together. This meant that one pen contained ten piglets and the other one housed eight piglets (seven after one piglet died from pneumonia). The pens measured 4.95 x 4.0 meters. The floor was covered with straw and some toys were provided; ropes that are used to bind straw bales, wood and dog toys to bite in.

The piglets were housed in their pens from the beginning of May, and the experiments ended in mid-October 2010. Nights were still chilly at the start of the experiment, some degrees Celsius under or above zero. Therefore the pens contained a 'nest' where the piglets could sleep and where it was warmer than outside, with straw inside and on the roof. The roof of the nests could be lifted up to make it cooler inside or lowered to make it warmer inside. The nests measured 1.52 x 2.55 meter. Ambient temperatures (which were pretty much the same as inside the building) ranged from about 10 degrees Celsius in October to about 35 degrees Celsius in July. On hot days, the upper shutters of the pens were opened during testing for fresh air and the pigs were sprayed with water when they were in the waiting area. A radio was tuned on from 7.00 till 19.00 h. Excretions were removed every day and the whole pen (including straw) was cleaned every week. The piglets were weighed once a month.

In the morning the animals received about 1/3 and in the afternoon about 2/3 of their total amount of food per day. Scatter feeding was used, because feeding from a trough can lead to more competition. The piglets received normal quantities of commercial piglet food during their growth phase. Water was provided ad libitum in their pen via an automatic drinking nipple. From July on, the pigs received food for breeding sows that was low in energy in order to let them grow less fast. Sometimes they received some old bread to eat and once they received apples, raisins and carrots.

Before starting the experiment, a veterinarian checked the piglets and declared them physically healthy.

Back test

When the piglets were 21 days old, they were all exposed to a back test ²⁶. Per litter, the piglets were taken from their pen and driven in a wheelbarrow to a corridor. Then, the piglets that were used for the back test were taken out of the wheelbarrow individually. The piglets

were put on their back on a plastic covered oat bag placed on a table. One person kept the piglet's forepaws between right thumb and forefinger. The left hand was placed gently on the hind legs. Another person operated a stopwatch and started the timer within three seconds after putting the piglet on its back (when the piglet stopped struggling or after three seconds). The piglet was held for 60 seconds in this position. The tests were recorded with a video camera. Some back tests could be performed only by one of the experimenters and consequently, the behaviours could not be scored during testing. We therefore decided to score all behaviours from the video recordings. The following behaviours were scored from the video recordings:

- Latency to struggle (in seconds)
- Latency to vocalize (in seconds)
- Number of vocalizations (using a counter).
- Number of struggles with at least the hind legs. We did not score a struggle when the piglet only stretched its hind legs.

Liesbeth Bolhuis from Wageningen University, who taught us how to perform the back test, recommended that the test should be performed twice, at an age of about 10 and 17 days old. If the pigs are older than approximately three weeks, they become too heavy and too strong to handle. We had to wait for the approval of the ethical committee for animal experiments, the DEC (Dier Experimenten Commissie) to perform the back test. Because by the time of approval the pigs were already about 21 days old, we could perform the back test only once at 21 days.

We decided not to classify the pigs as either HR or LR, because we could not find an evident correlation between number of struggles and number of vocalizations. Neither did we have a good criterion for what 'few' vocalizations nor 'many' vocalizations are in order to classify the animal as HR or LR in case of exactly two struggles.

Testing Apparatus

In Figure 1 the timeline of the experiment is shown (panel A) as well as the testing apparatus (panel B, see also Figure 3) which was used during the experiment.

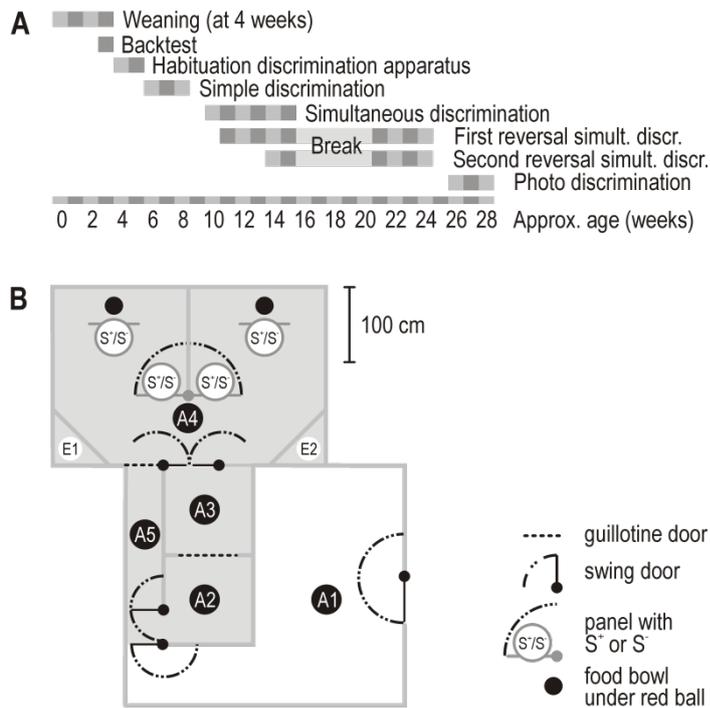


Figure 1. Timeline and testing apparatus.

Panel A timeline and panel B testing apparatus. During simultaneous discrimination learning, the pigs were transferred to the next phase after reaching the respective criterion, except for the photo discrimination task that was started when all pigs were approximately 26 weeks old. Note that there was a break of 5 weeks in which no training was given (due to holidays and reconstruction work in the stable).

Pigs stayed in waiting area A1 (8.9 m²) in order to wait for their session to start. At the start of their session a pig entered A2 (119 cm x 119 cm) while the experimenters prepared the stimuli and rewards. Then it entered A3 (120 x 119 cm) where it could see the visual stimuli (S+/S-) through a swing door for about a second. After that, the swing doors opened and the pig entered A4 (238x 361 cm). After choosing a stimulus, the pig returned via A5 (50 x 239 cm) either again to A2 or to the waiting area at the end of a session. Experimenters stayed behind partitions (E1 and E2) while the animal was choosing and made no eye contact.

During testing periods, when waiting for their session to start, the pigs stayed together in the waiting area (A1 in Figure 1), next to the testing apparatus.

At the start of their session, a pig entered A2 while the experiments prepared the visual stimuli and rewards. Doors could be opened by a system of ropes and pulleys. Then, the pig entered A3, where it could see the stimuli through open swing doors. There were two pairs of frames with visual stimuli (S+/S-) both on the left and right side of A4. One pair was closer (95 cm) to the swing door between A3 and A4 than the other pair (180 cm). The visual stimuli were placed in frames made of a wooden frame and a Perspex front. The swing doors were opened when the pigs had looked through them for about one second. After that, the pig had the opportunity to choose the left or right stimulus.

Under the stimuli, red balls were present which the piglets had to lift up (Figure 1 and 3). Under the balls, a food bowl was present, which was put in a holder that was attached to the floor of the apparatus. In the bowls, the rewards were placed. The bowls could be removed from the holder. In the space under both bowls, three M&M's were placed in order to prevent the pigs from choosing the correct side by smelling the rewards. The experimenters stayed behind two partitions that were placed in the upper and lower right corners of A4 (E1 and E2) and did not interact or have eye contact with the animal before a trial ended. After choosing a stimulus (choosing is defined as touching a ball), the pigs left the apparatus via corridor A5 in Figure 1, guided by one of the experimenters. The pig either went to A2 again, for a next trial, or at the end of a session entered waiting area A1.

For the photo experiment, the same testing apparatus was used. However, the visual stimuli used were larger and therefore the frames in which the photos were placed were also larger (65 x 65 cm). The frames at the front were made mobile; they could swing by means of a hinge attached to the partition between them. This was done in order to give the pigs (which had grown to a weight of about 85 kg on average) more space to reach the balls.

During testing, a radio was tuned on to prevent startling from unexpected noises. The testing apparatus, the balls and the food bowls were cleaned every day after testing.

Visual stimuli

Visual stimuli A and B (Figure 2) measured 17.5 x 17.5 cm and were printed on white A2 paper. Visual stimuli C-G (Figure 2) were 27.75 x 27.75 cm and were taken about four weeks before the experiment started in the waiting area and corridor. All photographs showed pigs from pen 1, one month before starting the experiment. So for the pigs of pen 1, the pigs shown on the photos were familiar, whereas for the pigs of pen 2 the photos showed unfamiliar pigs. This was done to investigate whether pigs see photos as representations of real animals in the generalization phase⁴⁰. The generalization phase means that the S+ pig from the first phase is shown from profile view instead of frontal view, combined with different other pig faces and profiles. Subjects that are confronted with photos of familiar pigs would learn this generalization faster than pigs confronted with unfamiliar pigs.

The photos were manipulated in Adobe Photoshop; the original background of the images was removed and replaced by a neutral gray background (gray 9 C). Care was taken to reproduce the photographs with a similar ratio between image and background.

We chose to start with the five sharpest photos, because it appeared that some photos were not 100% sharp. Siblings got the same pair of photos and no pair consisted of the same two photos. We chose the photo pairs by combining heads of pigs with a different colour (brown

versus pink), spots on nose or head, or a different ear position. From the pairs one photo was selected to be S+. The rewarded photographs did not show the two brown pigs, because there were only two brown pigs and seven 'normal' coloured pigs. If the photo of a brown pig would have been the S+, it may have been easier for the pigs in the next phases to just select an image with a brown colour, and it would be impossible to draw conclusions about their recognition ability.

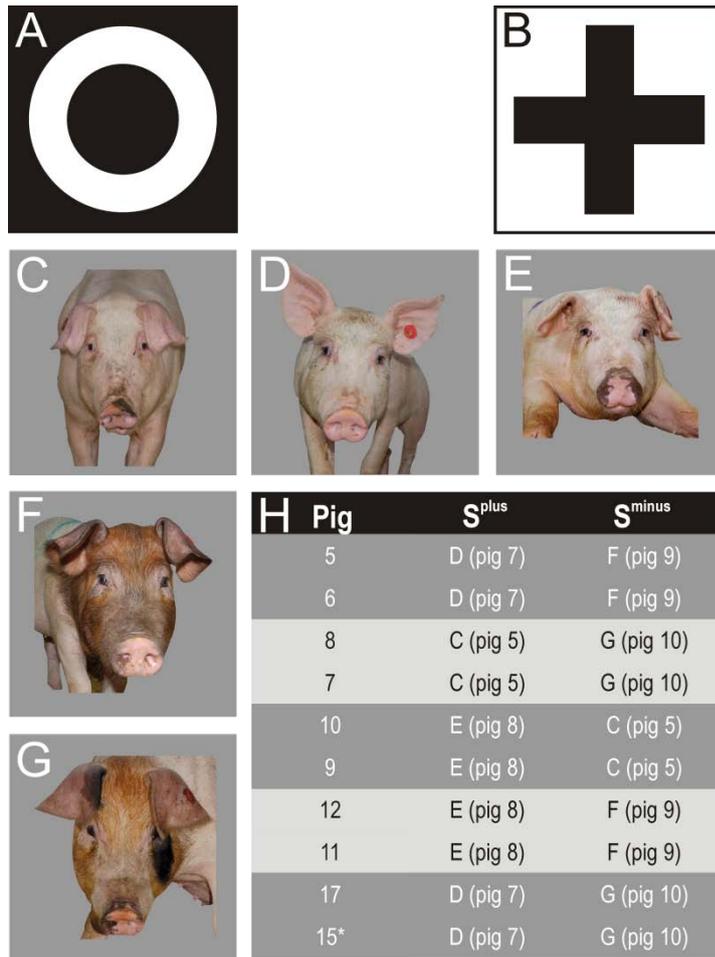


Figure 2. The two geometric visual stimuli depicted in panels A and B were used to train pigs in the simple discrimination task. For pen 1, stimulus A was the S+. For pen 2, stimulus B was S+. The portrait photographs of pigs depicted in panels C-G were used as stimuli in the photograph discrimination task. The 5 pigs performing best in the simple discrimination task and their sibling sisters (except for pig 17) were used in the photograph discrimination task (e.g.: pig no. 10 was one of the five best performing pigs, and pig no. 9 is her sister). Pigs used came from pen 1 and pen 2. Which photographs were used as S+ and S- is listed in panel H (C-G in panel H refer to the corresponding photographs).

Procedure simple discrimination

Habituation

Four days after the piglets were group-housed, the habituation phase began. For twelve days the piglets could habituate to their new pen and pen mates, the experimenters, the corridor, the waiting room, the experimental area, M&M chocolates and the flashlight used in the shaping phase. Every day the two groups were habituated to everything outside their pens, during two sessions of approximately half an hour. The piglets habituated to the experimental area in groups, starting with all animals from one pen, then in groups of 3-4 animals, then in pairs, and finally they entered the arena individually. They received 2-3 sessions per phase. The pigs also learned to lift the balls (see Figure 3) with their nose in order to obtain an M&M. M&M's were placed under the right and left ball. No stimuli were present.



Figure 3. Piglets during the habituation phase eating M&M's (left) and the testing apparatus (right)

Shaping phase

During this phase, the piglets entered the testing apparatus (see Fig. 1 and 3) individually. The piglets had a fixed order in which they were tested. Only one stimulus was used, which was shown randomly left or right. The piglets from the two different pens had a different rewarded stimulus (see Figure 2). When the piglet stood in the 'waiting area' of the apparatus (A3 in Figure 1), with the head faced towards the swing doors, a flashlight flashed three times towards the stimulus in order to draw the pig's attention to the stimulus.

The two groups received at least one training session in the morning on every weekday. At the start of the experiment, testing progressed slowly and there was no time in the afternoon to do a second session with both groups. As a consequence, in the afternoon only one of the groups received an additional session. The sequence of testing the two groups changed every day: 1-2-1, 2-1-2, 1-2-2, 2-1-1 and so on. After approximately 14 sessions, the piglets performed fast enough to allow running two sessions a day with both groups. The sequence of testing the groups changed every day: 1-2-1-2, 2-1-2-1, 1-2-2-1, 2-1-1-2 and so on. A correct choice was rewarded with one M&M. A choice was defined as the animal touching a ball with its nose. The animals could thus walk to the wrong position without touching the ball, then turn back and choose the correct side.

Each session consisted of ten trials. If an animal made the wrong choice (so touched the ball on the side without the stimulus) during the first 50 trials, it was given the opportunity to go to the side with the stimulus and receive the reward. This was done to make sure the piglets would notice that there was a stimulus that was rewarded. However, if an animal made the wrong choice after the first 50 trials, it had to leave the test apparatus immediately without having the opportunity to visit the correct side. If an animal became unmotivated because it had made the wrong choice over and over again, it was allowed to go to the correct side after making a mistake and eat the M&M, or it was forced once to choose the correct side (by blocking the wrong side) in the next trial. This happened 25 times in the experiment or on average 1.5 times per piglet (Table 1).

In the beginning of the experiment, some animals tried to leave the testing area after some trials. If that was the case, they were allowed to leave and the next animal started its session. After testing all the other animals, these piglets were returned to the testing apparatus. Most of the times they were now motivated enough to complete the session.

One animal (number 10) showed a strong left side bias at the start of the shaping phase. Therefore, the stimulus was placed on the right side on every trial, until the piglet went to the right side twice. Then, testing was continued with a random schedule.

Our criterion for the shaping phase to end was a score of minimal 80% (8 correct trials in a series of 10 trials) during two successive sessions. But by observing their behaviour, it seemed that some piglets did not understand the task, even though they had scored twice 80%. For example, they chose the correct side when the stimuli were alternated between left and right. But when a stimulus was twice on the right or left side, the animal did not choose twice that side, but kept alternating. So it was possible that only by alternating a piglet performed 80% correct twice (when the schedule was roughly l-r-l-r and so on and when it started with a correct choice). Therefore, we introduced an additional criterion: the piglets had to score twice 80% during two consecutive sessions and then again 80% twice (not

necessarily in consecutive sessions). As a consequence, some piglets continued to the next phase after reaching the criterion of learning (when the new criterion was not applied yet), whereas others that had reached this criterion received additional trials before starting the next learning phase. Due to insufficient administration, some piglets performed more than four times 80% before going to the next phase. Table 2 lists the number of trials that each piglet received.

Piglets continued to the next phase only if they reached the criterion. At a certain moment, one piglet could therefore be in the shaping phase, whereas another one was already in the training phase or further.

Table 1. Number of missed trials because of demotivation and number of forced trials or correction trials per piglet

Pig number and group (Low or Normal birth weight)	Number of missed trials	Number of times forced choice or correction trials
1 L	3	5
2 N	4	9
3 L	0	3
4 N	2	3
5 L	1	3
6 N	6	6
7 L	0	5
8 N	0	2
9 L	5	0
10 N	0	3
11	4	6
12	6	7
14 N	45	8
15 L	1	5
16 N	0	6
17 L	0	9
18 N	4	9

In this table the number of missed trials is shown in the second column. Sometimes pigs were really unmotivated and tried to leave the test apparatus or needed a lot of time to make a choice. If they were really unmotivated, they were allowed to leave the test apparatus because it cost too much time and they would not learn in a state like that. The third column shows the number of forced choices or correction trials. If an animal made too many consecutive errors, they sometimes got unmotivated too. Therefore they were forced to go to the site with the reward in the next trial, or they were allowed to go to the rewarded stimulus and eat the reward after making an error.

Table 2. Individual piglets and the number of trials they received after criterion of learning and the total number of sessions in which they performed 80% or more

Piglet	Shaping phase		Training phase				Reversal	
	Nr. of trials after criterion of learning	Nr. of sessions performed 80% in total	Nr. of trials after criterion of learning	Nr. of sessions performed 80% in total	Nr. of trials after criterion of learning	Nr. of sessions performed 80% in total	Nr. of trials after criterion of learning	Nr. of sessions performed 80% in total
1	40	5	20	4				
2	0	2	40	6				
3	70	8	70	5				
4	60	4						
5	20	3	40	6	40	4		
6	0	2	10	3				
7	0	2	10	3				
8	0	2	50	5	40	4		
9	40	6	30	4				
10	10	3	40	5	20	4		
11	0	98	2	7	30	5		
12	40	4	30	4	20	4		
14	10	3	70	4				
15	40	6						
16	0	40	2	6	280	10	10	3
17	0	2	70	6	50	5		
18	140	6	40	5				

In this table the number of trials a piglet received per phase after it reached the criterion of learning is listed. In the second column the total number of sessions is shown in which the piglet performed 80% or more. Empty cells mean that the piglet did not reach this phase or did not reach criterion of learning during that particular phase. Piglet 11 and 16 performed the shaping and the training phase twice because they did not learn the training phase as fast as the others. Therefore they returned to the shaping phase. When they had completed that phase, they continued with the training phase. The data shown are from the first (left side cell) and second time (right side cell) they performed the shaping and training phase.

Training phase

During this phase, two stimuli (see Fig. 2) were used that alternated between left and right, determined by a random schedule. The rewarded stimulus during the shaping phase was still rewarded. A correct choice was rewarded with one M&M. The flashlight was not used anymore to direct the attention of the piglets to the stimuli. The same learning criterion was applied as in the shaping phase (new criterion). Unfortunately, due to incomplete administration, not all the piglets received the same amount of sessions *after* reaching the learning criterion (see Table 2).

Overall, the animals needed fewer sessions to complete the training phase compared to the shaping phase. However, training lasted very long took (18 and 27 sessions) in piglet

number 11 and 16. It is possible that they never really learned the shaping phase, due to alternation in consecutive trials and performing 80% by chance. Therefore, the training phase was stopped and training was continued with only one stimulus (shaping phase). When these animals reached the criterion of learning during the shaping phase, training was continued with two stimuli (training phase).

Reversal 1

During this phase, the previously rewarded stimulus was no longer rewarded. Instead, the previously unrewarded stimulus now became rewarded. Training was continued till the animals reached criterion of learning. After that they continued for some sessions doing the reversal until they had scored a total of four times 80% correct choices (two in consecutive sessions and after that two more). Unfortunately, not all the piglets received the same amount of sessions after reaching the learning criterion (see Table 2).

Reversal 2

During the last phase, the first stimulus (that had been rewarded in the shaping and training phase and was unrewarded in reversal 1) became rewarded again.

Non-testing period

After a non-testing period of five weeks the experiment was continued. Animals were less motivated and slower and therefore only received 1-2 sessions a day, as in the beginning of the experiment.

Motivation

Two of the animals were found to lack motivation to perform the task, especially after the non-testing period. To develop a valid criterion for excluding non-motivated animals from the study, we assessed motivation in all animals during five sessions by measuring the time from opening the double swing door till the animal touched one of the balls with its nose. Then, we calculated the average time between opening of the swing doors and touching the ball. It did not appear that the slowest animals in performing the test were also the animals that learned slowest. Consequently, there was not a good criterion to exclude the unmotivated animals. However, one of the unmotivated animals (number 14) was the sister of the piglet that died during the habituation phase. Therefore, we decided not to continue training her in the experiment.

End of training

We wanted to have as much piglets as possible to reach criterion of learning in the reversal phase 1, to be able to calculate correlations between back test behaviours and reversal learning. However, the pigs needed a lot more trials to learn the reversal than the training phase and they were getting really heavy. This makes testing more difficult. Therefore, training was stopped when all piglets that were in the reversal phase had received at least the median (100 trials) of the number of trials to reach criterion in the training phase. Consequently, also the piglets that were in other phases stopped training.

Note

The last session of pen 2 was excluded from data analysis, because this group of animals received one session more than the piglets in pen 1.

Photo experiment

Before starting the experiment, the pigs had a short habituation session of six trials to get used to the new photo frames. No photos were shown during habituation. M&M's were put at both sides.

During the first phase of this experiment, two photos (front view) were used which were shown randomly left or right. No correction procedure was used, because the piglets already knew the apparatus and the task of choosing between two stimuli. Because the pigs were now much heavier (average weight approximately 85 kg) than when starting the first experiment, the reward was two M&M's instead of one. During testing all 17 pigs, so also the ones that were not used in the experiment, stayed in the waiting area. Each session consisted of ten trials. The piglets received at least one session a day and a maximum of three sessions a day, depending on the time available and speed of testing. Most of the testing days consisted of two sessions.

According to the experimental protocol, the pigs would switch to the next training phase when they had performed four times 80% correct in a series of five sessions. From the first discrimination experiments though, we had established a maximum number of trials. If none of the pigs would learn the first phase before this maximum, testing would stop. This maximum was the median of learning the shaping phase in the first experiment. The maximum number of trials was 289. This was done because the pigs were getting really big (100-130 kg) and testing became more difficult. We also argued that if pigs use face recognition in their daily life, they would learn this relatively easily.

After one week of testing, the waiting space was altered. Because the pigs had grown so big, the space was too small and the animals seemed to behave more aggressive towards each other than before. The partition was removed so that the space grew from 8.9 m² to 12.8 m².

Statistics

Descriptive statistics per variable and group (means, standard errors of the mean) were calculated and are shown in tables 4-5 and figures 5-28.

Effects of birth weight were analysed with a one-factorial analysis of variance with the factor birth weight (low vs. normal birth weight).

Correlations between birth weight and number of struggles, latency to struggle, number of vocalizations and latency to vocalize were calculated with a Pearson correlation test across all piglets that underwent the back test (including the reserve piglets and the one that died). Correlations between number of trials in the shaping and training phase and number of struggles, latency to struggle, number of vocalizations and latency to vocalize were calculated with a Pearson correlation test. This was done for the piglets that performed the discrimination task. No correlations were calculated for the reversal phase, because only five piglets reached the criterion of learning in that phase.

For the first 15 sessions (divided in three blocks of five sessions each) of the shaping phase, average percentages correct choices, average percentage left or right, average percentage alternations and average percentage longest series were calculated. Calculations were made first per session and then per block. Average percentage correct choice was calculated by dividing the number of correct choices by the total number of trials in a particular session. The percentage of alternations was defined as the total number of spontaneous alternations (left-right or right-left) in a session divided by the number of trials in the session minus one; minus one because in the first trial the animal cannot go to the same side as the previous trial. The average percentage left or right was calculated by counting the number of trials per session that a piglet choose the left or right side and dividing that by the total number of trials in that session. Longest series were calculated by counting per session the greatest number of trials an animal went to one side successively (either left or right), and dividing that number by the total number or trials in that session.

Percentages were calculated instead of number of trials, because some sessions consisted of six or 14 trials instead of 10. All pigs of pen two received two sessions of six trials during a series of 87 sessions and animal 18 received two sessions of 14. Animal 15 received one session of 14 trials. Animal 12 received one session of 8 trials; animal 16 received one

session of four, one of seven and one of 14. Animal 17 received one session of four and animal 14 one of four and one of 14. Note that finally all animals had received the same amount of trials. Some sessions had an abnormal number of trials because the animals tried to leave the testing apparatus. Then we let them out and tried to test them again after a while. Most times the animals completed the session, but not always. This was mainly in the beginning of the experiment. Some trials were excluded from data analysis, because we forced the pig to go to the correct side because it was unmotivated (and it was not a free choice anymore). In that case, the session consisted of nine trials instead of 10. The number of sessions that had an abnormal number of trials varied per pig, but ranged from zero to five sessions out of 87. The number of trials in those sessions ranged from five to nine.

The effects of birth weight and training on the behaviour of the piglets in the test were analysed by a two factorial ANOVA with the factor birth weight (low vs. normal birth weight) and the repeated measure factor block (blocks 1-3).

Results

Raw data can be found in the appendix (page 48).

Birth weight

The analysis confirmed that the mean birth weight of the low birth weight group was significantly lower than that of the normal birth weight group ($F_{1, 15} = 35.66$ $p < 0.0001$; see Figure 5).

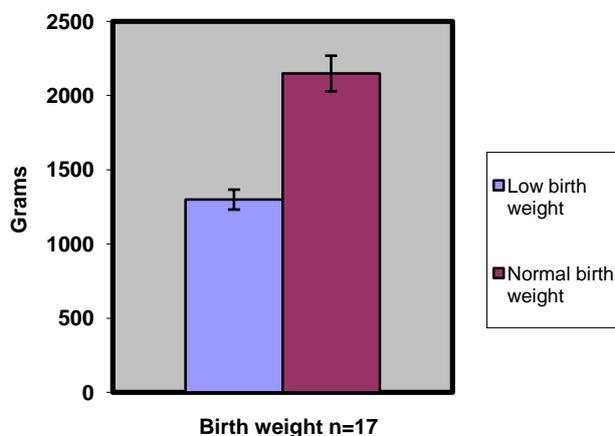


Figure 5. Average birth weight of the different groups

Back test

Figures 6-9 depict the results of the back test.

Number of struggles ranged from zero to five, but the main part of the piglets (8) made two struggles (see appendices).

Correlations between back test behaviours are found in Table 4.

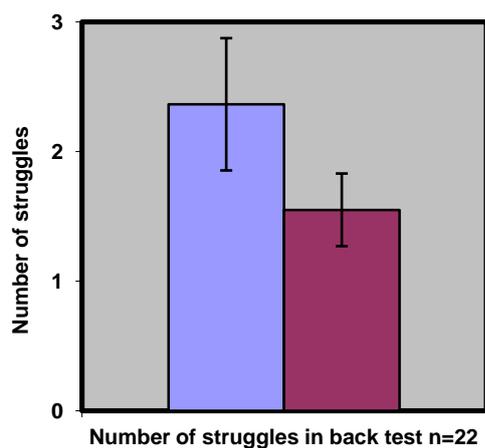


Figure 6. Average number of struggles in back test of tested piglets and four reserve piglets

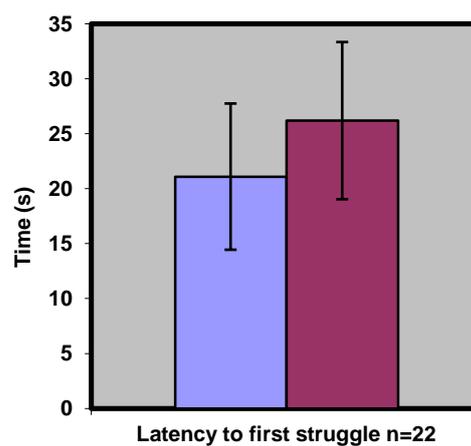


Figure 7. Average latency to first struggle

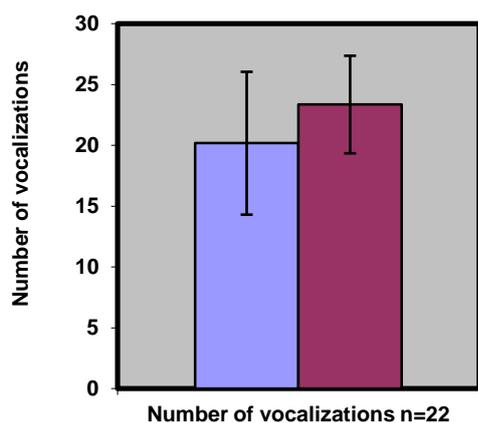


Figure 8. Average number of vocalizations

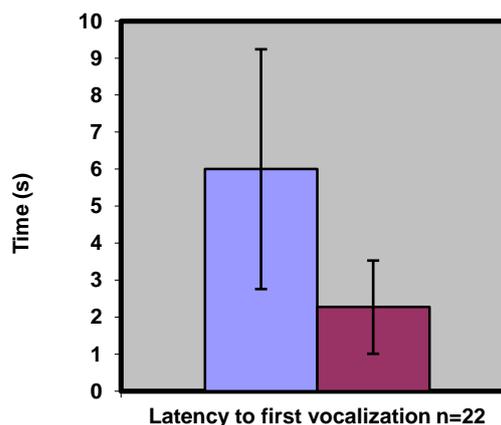


Figure 9. Average latency to first vocalizations

No differences were found between low birth weight piglets and normal birth weight piglets in the number of struggles they made during the back test ($F_{1, 20}=1.98$ $p=0.175$), in the latency

to first struggle ($F_{1,20} = 0.27$ $p = 0.610$), the number of vocalizations ($F_{1,20} = 0.20$ $p = 0.660$) or the latency till first vocalization ($F_{1,20} = 1.15$ $p = 0.297$).

The Pearson correlation test showed a significant, but moderate negative correlation between the number of struggles and birth weight ($r_{PM} = -0.445$ $p = 0.038$ $N = 22$; see Table 4), indicating that the lower its birth weight, the more a piglet struggled in the back test.

A significant, but moderate negative correlation was also found between number of struggles and latency to first struggle ($r_{PM} = -0.63$ $p = 0.002$ $N = 22$, see Table 4), i.e. piglets with more struggles started struggling earlier. The correlation between the number of vocalizations and the latency to first vocalization was almost significant ($r_{PM} = -0.41$ $p = 0.058$ $N = 22$; see Table 4).

Table 4. Product-moment correlation coefficients (r_{PM}) between behaviours from the back test. The correlation coefficients are calculated across 22 piglets (i.e. the piglets used in the discrimination task, the piglet that died and the four reserve piglets)

	Number of struggles	Struggle latency	Nr.of vocalizations	Vocalization latency
Birth weight	$r_{PM} = -0.445$ $p = 0.0379$	$r_{PM} = 0.309$ $p = 0.1623$	$r_{PM} = 0.022$ $p = 0.9226$	$r_{PM} = -0.131$ $p = 0.5616$
Number of struggles		$r_{PM} = -0.630$ $p = 0.0017$	$r_{PM} = 0.356$ $p = 0.1041$	$r_{PM} = 0.063$ $p = 0.7805$
Struggle latency		$r_{PM} = -0.453$ $p = 0.068$	$r_{PM} = -0.368$ $p = 0.0922$	$r_{PM} = -0.042$ $p = 0.8515$
Number of vocalizations				$r_{PM} = 0.410$ $p = 0.058$

When calculated across all piglets, no significant correlation was found between the number of struggles and the number of vocalizations ($r_{PM} = 0.356$ $p = 0.104$ $N = 22$; see Table 4).

However, when only the data of the piglets we used in the experiment (excluding the reserve piglets and the one that died) were considered, there was a significant positive, moderate correlation ($r_{PM} = 0.493$ $p = 0.045$ $N = 17$; see Table 5).

Table 5. Product-moment correlation coefficients (r_{PM}) between behaviours from the back test and number of trials in shaping and training phase. Correlations are calculated across the data of 17 piglets used in the visual discrimination experiment.

	Nr. of struggles	Struggle latency	Nr. of vocalizations	Vocalization latency	Nr. of trials shaping	Nr. of trials training
Birth weight	$r_{PM} = -0.418$ $p = 0.095$ $n = 17$	$r_{PM} = 0.350$ $p = 0.168$ $n = 17$	$r_{PM} = 0.129$ $p = 0.621$ $n = 17$	$r_{PM} = 0.158$ $p = 0.544$ $n = 17$	$r_{PM} = -0.242$ $p = 0.349$ $n = 17$	$r_{PM} = -0.017$ $p = 0.953$ $n = 15$
Nr. of struggles		$r_{PM} = -0.510$ $p = 0.037$ $n = 17$	$r_{PM} = 0.493$ $p = 0.045$ $n = 17$	$r_{PM} = -0.006$ $p = 0.983$ $n = 17$	$r_{PM} = 0.455$ $p = 0.067$ $n = 17$	$r_{PM} = 0.390$ $p = 0.150$ $n = 15$
Struggle latency			$r_{PM} = -0.453$ $p = 0.068$ $n = 17$	$r_{PM} = 0.105$ $p = 0.689$ $n = 17$	$r_{PM} = -0.068$ $p = 0.796$ $n = 17$	$r_{PM} = 0.092$ $p = 0.745$ $n = 15$
Nr. of vocalizations				$r_{PM} = -0.345$ $p = 0.175$ $n = 17$	$r_{PM} = 0.628$ $p = 0.007$ $n = 17$	$r_{PM} = 0.144$ $p = 0.608$ $n = 15$
Vocalization latency					$r_{PM} = 0.183$ $p = 0.483$ $n = 17$	$r_{PM} = 0.289$ $p = 0.296$ $n = 15$
Nr. of trials shaping						$r_{PM} = 0.380$ $p = 0.162$ $n = 15$

Shaping phase

A significant correlation was found between number of trials in the shaping phase and the number of vocalizations in the back test ($r_{PM} = 0.628$ $p=0.007$ $N=17$; see Table 5). For the number of struggles and number of trials in the shaping phase, the positive correlation was almost significant ($r_{PM} = 0.455$ $p=0.067$ $n=17$; see Table 5).

No significant differences were found between low birth weight piglets and normal birth weight piglets in the percentage correct visits during the first five sessions of the shaping phase ($F_{1,15} = 0.84$ $p = 0.375$), nor for the percentage alternations ($F_{1,15} = 1.47$ $p = 0.244$), percentage choices right ($F_{1,15} = 1.04$ $p = 0.324$), percentage choices left ($F_{1,15} = 1.04$ $p = 0.324$), or percentage longest series ($F_{1,15} = 0.06$ $p = 0.81$). See Figures 10-14.

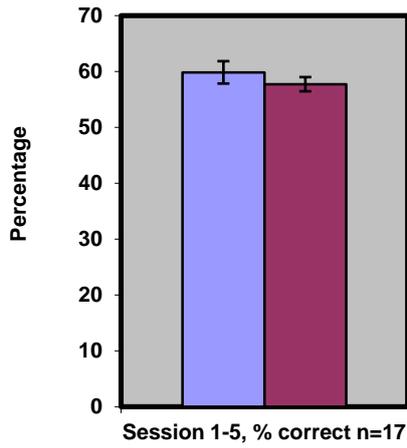


Figure 10. Average % correct, sessions 1-5

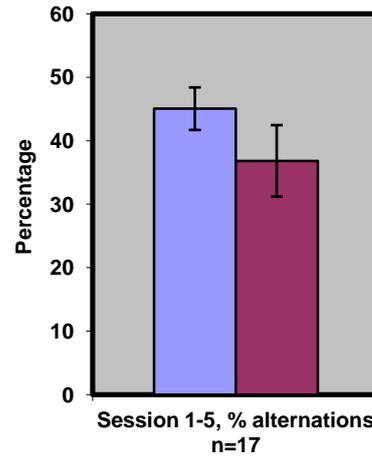


Figure 11. Average % alternations, sessions 1-5

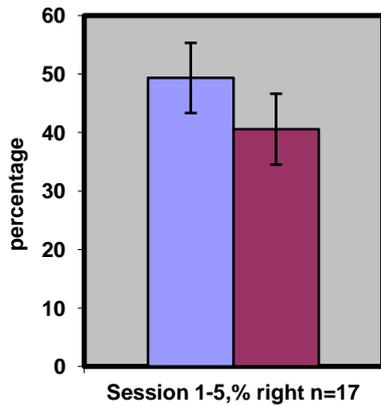


Figure 12. Average % choices to the right, sessions 1-5

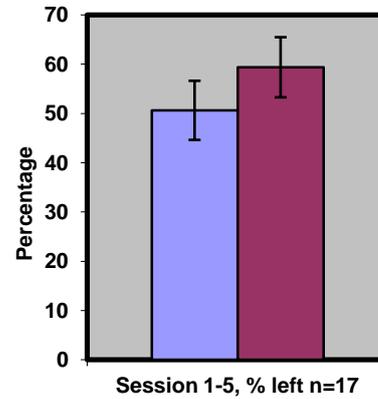


Figure 12. Average % choices to the left, sessions 1-5

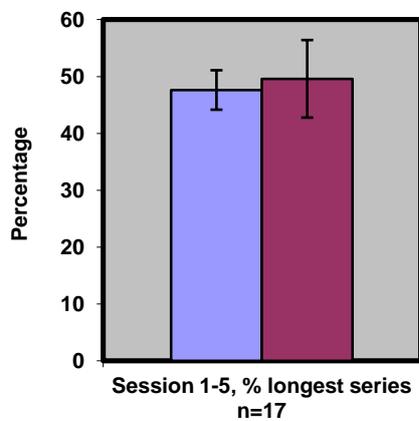


Figure 14. Average % longest series, sessions 1-5

For the sessions 6-10 of the shaping phase, there were no significant differences between the two groups; nor for the percentage correct choices ($F_{1,15} = 1.40$ $p = 0.255$), the percentage alternations ($F_{1,15} = 0.74$ $p = 0.404$), percentage choices right ($F_{1,15} = 0.63$ $p = 0.440$), percentage choices left ($F_{1,15} = 0.63$ $p = 0.440$) or percentage longest series ($F_{1,15} = 0.01$ $p = 0.905$). See Figures 15-19.

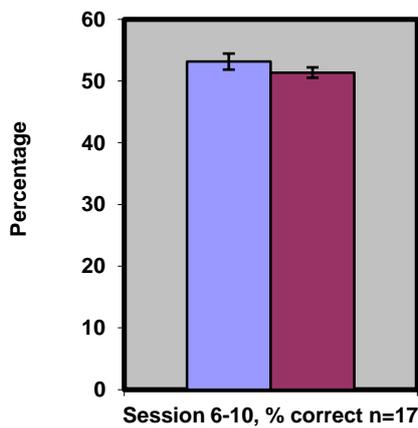


Figure 15. Average % correct, sessions 6-10

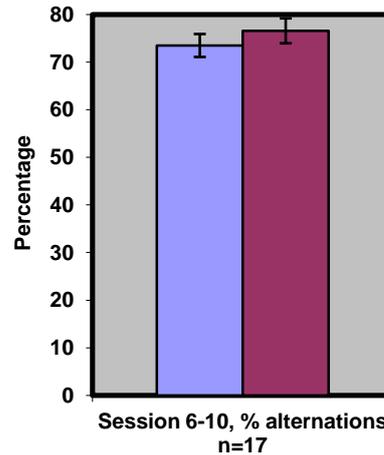


Figure 16. Average % alternations, sessions 6-10

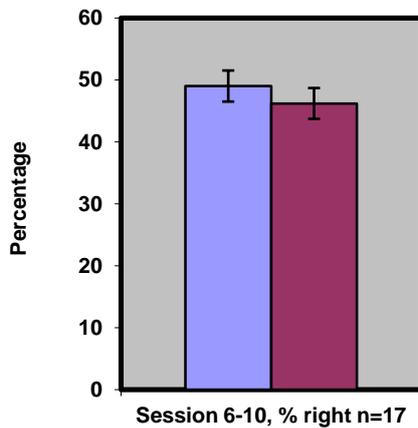


Figure 17. Average % choices to the right, sessions 6-10

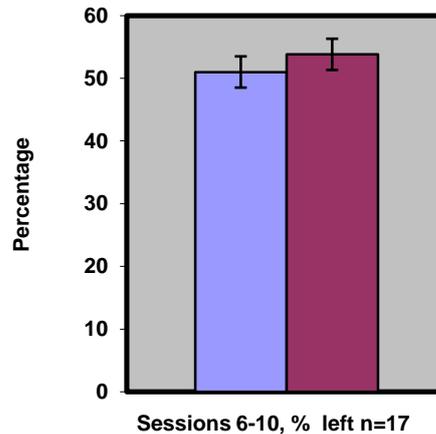


Figure 18. Average % choices to the left, sessions 6-10

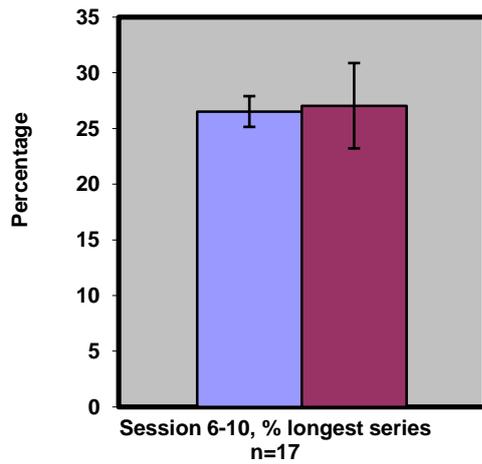


Figure 19. Average % longest series, session 6-10

For the sessions 11-15 of the shaping phase we did not find any differences in the learning behaviour of the two groups. See Figures 20-24. The piglets did not differ in the percentage correct choices ($F_{1,15} = 0.04$ $p = 0.835$), percentage alternations ($F_{1,15} = 0.05$ $p = 0.825$), percentage choices right ($F_{1,15} = 0.17$ $p = 0.6858$), percentage choices left ($F_{1,15} = 0.17$ $p = 0.686$) or percentage longest series ($F_{1,15} = 0.06$ $p = 0.810$).

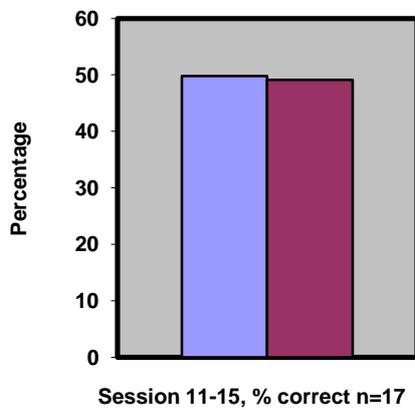


Figure 20. Average % correct, sessions 11-15

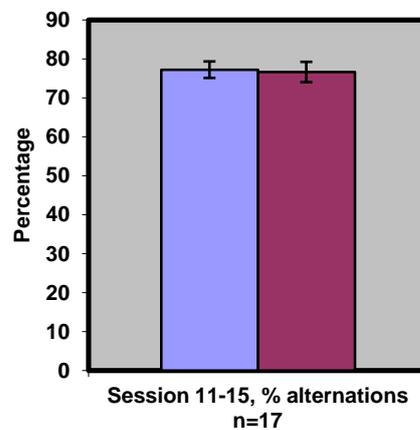


Figure 21. Average % alternations, sessions 11-15

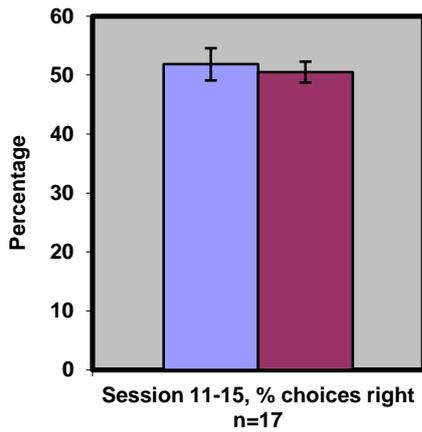


Figure 22. Average % choices to the right, sessions 11-15

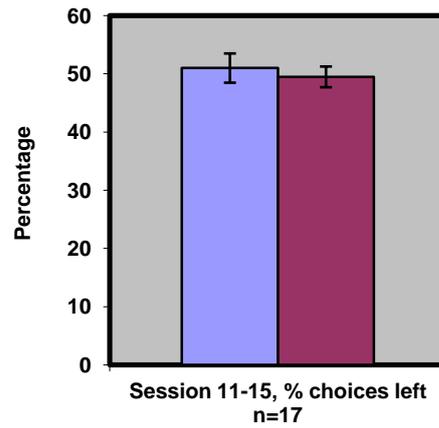


Figure 23. Average % choices to the left, sessions 11-15

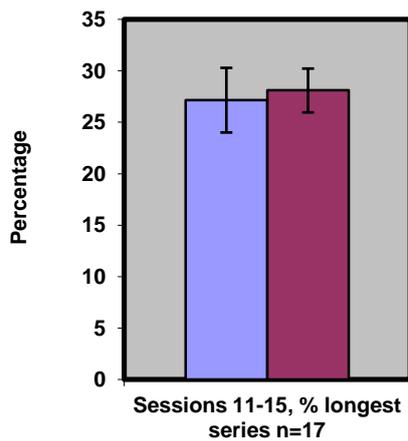


Figure 24. Average % longest series, sessions 11-15

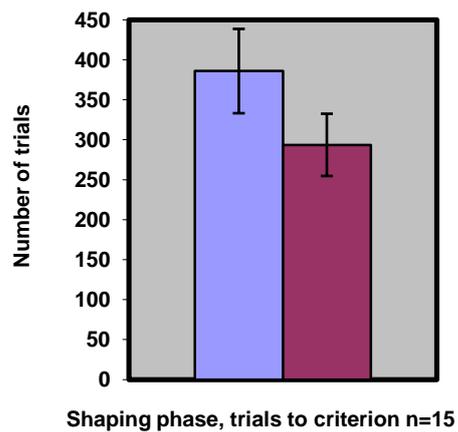


Figure 25. Average number of trials to criterion in shaping phase.

The two weight groups of piglets did not differ in the number of sessions they needed to learn the shaping phase ($F_{1,15}=2.04$ $p=0.173$). See Figure 25. No significant correlation was found between birth weight and the number of trials needed to reach criterion ($N=17$ $p=0.350$ $r_{PM} = -0.242$).

Learning behaviour shaping phase

For the behaviour during the first 15 sessions of the shaping phase, no differences were found between subjects for the percentage correct choices ($F_{1,15} = 0.78$ $p= 0.391$). However, there was found a significant decrease in the percentage correct choices over the first three

blocks (Blocks: $F_{2,30}=20.42$ $p<0.0001$). This decrease was similar for the two groups (Blocks x group interaction: $F_{2,30}=0.13$ $p=0.882$).

The two groups did not differ in the average percentage alternations during the first fifteen sessions ($F_{1,15}=0.62$ $p=0.444$). However, across the three successive blocks, the percentage alterations increased (Blocks: $F_{2,30}=68.44$ $p < 0.0001$) similarly in both groups (Blocks x group interaction: $F_{2,30}= 1.38$ $p=0.266$).

The groups did not differ in their preference to choose the right side during the first fifteen sessions ($F_{1,15}= 1.01$ $p=0.330$). The percentage of choosing the right side did not change during the three successive blocks of 5 sessions (Blocks: $F_{2,30}=1.86$ $p=0.173$). No interactions between group and choosing the right side were found (Blocks x group: $F_{2,30}= 0.74$ $p = 0.485$).

The low and normal birth weight piglets did not show a different percentage longest series ($F_{1,15}=0.07$ $p=0.789$) in the first fifteen sessions. Though, both groups showed a significant decrease in the percentage longest series over the blocks (Blocks: $F_{2,30}= 28.12$ $p<0.0001$). No interactions were found (Blocks x group: $F_{2,30}= 0.03$ $p= 0.975$).

All piglets reached the criterion of learning of the shaping phase. When only looking at the piglets that performed the task, a positive correlation was found between number of vocalizations in the back test and number of trials to criterion in the shaping phase ($r_{PM} = 0.628$ $p= 0.007$ $N=17$). A trend was seen for the correlation between number of struggles and number of trials to criterion of the shaping phase ($r_{PM} = 0.455$ $p= 0.067$ $N=17$; see Table 5).

Training Phase

Fifteen of the seventeen piglets learned the training phase. Of the piglets that did not learn the training phase, one piglet was of the low birth weight group and one of the normal birth weight group. The groups did not differ significantly in the number of trials they needed to learn the training phase, see Figure 26 ($F_{1,15}= 0.06$ $p= 0.808$). No correlation was found between number of trials to criterion and birth weight ($r_{PM} = -0.017$ $p=0.953$ $N=15$).

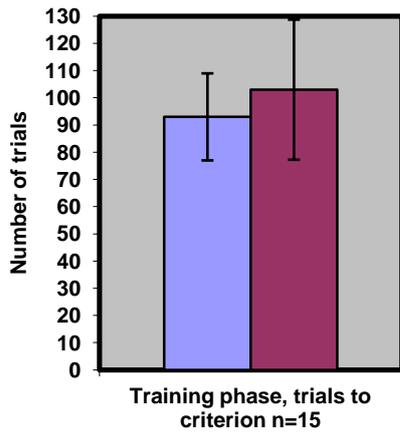


Figure 26. Average number of trials to criterion in training phase.

Reversal

Only five piglets learned the first reversal. Two of them were from the low birth weight group and three from the normal birth weight group. No differences were found in the speed of learning between the groups (number of trials to criterion), see Figure 27 ($F_{1,10} = 0.92$ $p=0.359$).

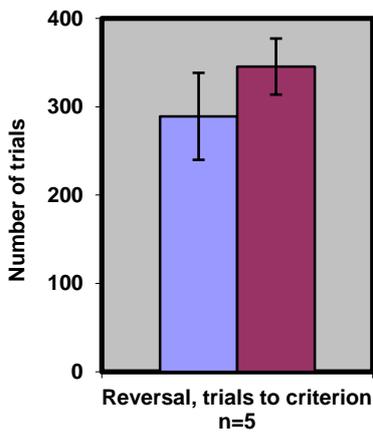


Figure 27. Average number of trials to criterion in reversal 1

Reversal 2

None of the animals learned the second reversal.

Motivation

The average time the piglets needed from opening of the folding doors till touching the ball nearly differed significantly ($F_{1, 15} = 4.47$ $p=0.0516$) between the groups. See Figure 28.

When analyzing the logarithm of the mean time, the difference was significant ($F_{1, 15} = 5.95$ $p=0.028$). The low birth weight group was quicker.

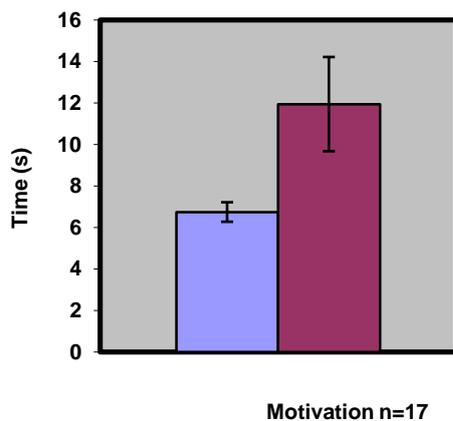


Figure 28. Motivation, expressed in time needed from opening of folding doors till touching the ball

Photo experiment

Not one of the pigs learned the task in the maximum number of trials (289) pre-determined for this experiment. The two 'smartest' pigs from the first experiment needed 170 and 230 respectively trials to learn the shaping phase (with one stimulus) in the first experiment.

Discussion

Back test & learning

We did not find a correlation between the number of vocalizations and the number of struggles in the back test. In contrast, Hessing *et al.* (1993)²¹ found that high resistant pigs (more than two struggles) vocalized more than non-resistant pigs (less than two struggles). However, they performed five back tests and we did only one per animal. We had also some problems scoring vocalisations from the videos, due to high levels of background noise. This could have influenced the data.

From populations in the wild it is known that animals show a bimodal distribution regarding coping style and personality, for example in great tits. For domestic animals it is not very clear and data may show a more normal distribution, unless you really select for coping style¹⁶. This may explain why we did not find a correlation between number of vocalisations and struggles, a clear distinction in coping style and extreme examples of coping styles.

A significant negative correlation was found between number of struggles and latency to first struggle. This means that the faster a piglet starts struggling, the more it struggles. This is in accordance with observations from Dr. Ir. Liesbeth Bolhuis, Wageningen University (pers. comm.).

Our results also indicate that there is a moderate negative correlation between birth weight ($r_{PM} = 0.445$) and the number of struggles in the back test; the lower the birth weight, the more a piglet struggles. This was only the case when all piglets that underwent the back test were used in the analysis. This result is in accordance with the hypothesis that 'low birth weight piglets struggle more during the back test' and what Bolhuis found over the years performing the back test with a lot of piglets (pers. comm.). These results make sense, because the very low birth weight piglets, which survive, must be strong and in some way pugnacious. This accords most to a proactive coping style. Also in human research there is evidence that low birth weight children are less adaptable and this might indicate a proactive coping style²⁷.

The hypothesis 'piglets that struggle and vocalise a lot in the back test have difficulties in learning reversals, but further have the same learning abilities as piglets with a more reactive coping style' can be partly rejected. Because there were only five piglets that learned the reversal we could not test the first part of the hypothesis. However, the second part we did test. We found that there is a positive moderate correlation between number of vocalizations and number of trials in the shaping phase; this means the more a piglet vocalized the more trials it needed to learn the shaping phase. An almost significant correlation was found between number of struggles and number of trials in the shaping phase. These results contrast with findings of Bolhuis (2004)²⁶. She reported that HR and LR animals performed equally well in learning a spatial discrimination task (a T-maze), but that LR animals needed fewer trials to learn the reversal. HR piglets in our case are piglet that struggle and or vocalise a lot.

An explanation for our results may be found in the suggestion that animals with a proactive coping style (which vocalize and struggle a lot), which are favoured in a stable environment, are less flexible in their behaviour and are more likely to develop behavioural routines¹⁶. This indicates that they cannot cope as well with changing 'environments' as animals with a

more reactive coping style. We assumed that learning a 'reversal' represents this changing environment. However, it may be possible that learning anything (for example, associating a visual stimulus with a food reward) also represents a 'changing environment' and that animals with a more proactive coping style perform less in overall learning. However, no correlations were found between number of struggles and vocalizations and the number of trials to criterion in the training phase. This contrasts with the suggested explanation.

Birth weight & visual discrimination learning

The results of the first experiment indicate that birth weight does not influence simple and simultaneous learning in pigs in a visual discrimination task; no differences were found between the groups in the number of trials to criterion in the shaping, training and reversal phase and with respect to learning strategies (alternations, percentage of choosing right or left side, etcetera). Correlations were neither found between birth weight and number of trials to criterion in the shaping and training phase. This result contrasts with reports about the effects of low birth weight on learning in humans^{5,6}. The hypothesis 'low birth weight piglets have lower learning abilities than normal birth weight piglets' can therefore be rejected. However, an experiment using the cognitive holeboard showed that low birth weight piglets need more trials than normal birth weight piglets to learn a reversal⁴⁴.

An explanation for the fact that we did not find differences is that a lot of studies done in humans on this topic do not exclude other problems like neonatal asphyxia and prematurity that may influence cognitive abilities. When these factors were excluded, no significant differences were found in one study between low and normal birth weight children⁸. So, if the piglets in this experiment neither suffered from above-mentioned complications, this could be a reason why we did not find differences in learning ability and behaviour.

Moreover, piglets suffering from the above-mentioned complications are less likely to survive; our group might be biased, because we could only choose from surviving piglets.

Another explanation for the fact that we could not find differences in learning ability or strategy is that the task may be too difficult for all pigs (floor effect). Even the 'smartest' piglet needed 170 trials to learn the first phase. Maybe a visual discrimination task is not well suited to assess learning in pigs. Pigs are known to rely more on olfactory and auditory cues in their daily life than on visual cues. They use olfactory cues for individual recognition and they have pheromones that carry specific messages¹. In a study by Hutson *et al.* (1993)⁴⁵ sows responded more to auditory and olfactory stimuli (playback of sow grunt, eucalyptus oil) than to visual stimuli (novel rod). However, Croney *et al.* (2003)⁴⁶ found that pigs do learn to use visual cues to locate a food source, although learning was slightly better when

provided with olfactory cues. Pigs also use visual displays; ears, tail and body posture are used for signalling¹. Their visual acuity is quite good⁴⁷.

In conclusion, there is no consensus about the question how good pigs' vision is and how they use it in their daily life. Another possibility is that pigs are more sensitive to and interested in visual stimuli that move, and less sensitive or unresponsive to static ones like the ones used in our study. This might explain why they learned the task slowly.

Moustgaard *et al.* (2004)²⁹ found that Göttingen mini pigs learned a visual discrimination task, but this task was a very simple white-black discrimination, which did not use different shapes. They used punishment (20 s of darkness) and a secondary reinforcer (a tone). However, the piglets in their experiment (on average 140 trials) learned the discrimination not faster than in our experiment (low birth weight piglets 93 trials, normal birth weight piglets 103 trials). This suggests that applying a punishment and a reinforcer does not speed up learning.

In this experiment, we used massed trials. However, it has been reported that animals learn faster when the trials are spaced⁴⁴. Spaced trials would be better to prevent spontaneous alternation, because the animal might forget which direction it chose in the previous trial. Spontaneous alternation may explain partly why the animals did not learn fast: when alternating all the time, the number of M&M's they receive is on average about five per session. This density of reinforcement may be sufficient for pigs to maintain the alternation behaviour. Consequently, the animals may not detect the contingency underlying the task rapidly, namely that one stimulus predicts reinforcement. Applying spaced trials though, would imply much more work and less time for testing.

Possibly the break of five weeks also delayed the learning process, and therefore only a few animals learned the first and second reversal. However, for rats a learning break was no problem (Dr. habil. Franz Josef van der Staay, Emotion & Cognition Group, Faculty of Veterinary Medicine UU, pers. comm.).

Within about one week the piglets learned the order in which they had to enter the testing area (descriptive behavioural observation). This means that they were able to learn this order in about ten 'trials'. This is very fast compared to the 170 to more than 600 trials they needed to master the shaping phase with visual stimuli. It is conceivable, that the order in which the piglets entered the experiment reflects some kind of hierarchy, which is known that they learn easily (Dr. habil. Franz Josef van der Staay, pers. comm.).

In conclusion, why the piglets learned the visual discrimination task so slow and other things a lot faster cannot be answered yet, because it is not clear in which way pigs use their vision in daily life and how good their vision is.

The experiment could not base upon a background of published data, and consequently, we had to implement some modifications in the running experiment. For example, we did not have a well-defined scenario for dealing with piglets that made a lot of mistakes or were unmotivated. The first applied criterion of scoring twice 80% did not work well, because it seemed that piglets could reach criterion without really understanding the task. The reason could be the use of a random schedule instead of a pseudo-random schedule. With a pseudo-random schedule there is a limitation to the number of alternations or the number of trials where the stimuli are shown consecutive left or right.

Because it seemed that some piglets did not understand the task, even though they reached the criterion of learning, we re-defined the criterion. The new criterion was not applied to all piglets, but we think this did not influence our general findings. Two animals returned to the shaping phase when they did not learn the training phase as fast as the other pigs. These *ad hoc* modifications may have had some influence on the results. We suggest defining a new, stricter criterion for learning a discrimination task in pigs. For example, a level of at least 80% correct choices in four out of five successive sessions would be a good criterion.

Referring to the motivation of performing this experiment, we can conclude that a low birth weight apparently does not have welfare implications for the pigs, because they learn equally well.

Motivation

The animals with a normal birth weight (which were usually still bigger, except two sisters) were less motivated than the low birth weight piglets. We measured motivation by the time they needed from opening the door till touching one of the balls. We observed that the big animals usually moved slower. It is not clear whether this reflects a lack of motivation or that they just move slower because they are heavier.

Photo experiment

For the photo discrimination experiment, the first hypothesis can be rejected, because the pigs did not learn the first phase of the experiment: they could not discriminate between two different pigs. In a previous experiment of our group, it was already tested whether pigs can learn to discriminate between photos of conspecifics. In that experiment, the pigs did not learn the task. It might be that pigs are just not able to discriminate between conspecifics using only visual information. But it was also possible that in that experiment the pigs did not understand that they had to pay attention to visual cues in order to obtain a reward, because they had no experience with other visual discrimination task. That is the reason we wanted

to use pigs in the photo experiment that had experience with visual discrimination tasks. However, this did not help them in learning the task.

Even though the pigs could not discriminate between the photos, they reacted differently to the photo stimuli than to the geometric stimuli in the first experiment: when the pigs saw the photos for the first time they all stood tense and motionless, stared at the photos, and some even jumped backwards and squealed briefly. They did not react like that when presented in the training phase of the first experiment with a new geometric stimulus. This suggests they consider the photos as a different category than the geometric stimuli.

Bovet and Vauclair (2000)⁴⁸ point out that 'pictures, being still or in motion, are abstractions from the reality they represent. Thus, even if birds predominantly use visual cues to identify social stimuli, auditory and olfactory information is also present in encounters with real conspecifics but absent in pictorial'. Moreover, pictures are abstract stimuli that lack the information of perceiving depth, and colours and size can be different from 'real world'⁴⁸. Therefore, we can conclude from the results of our study that pigs are not able to discriminate between faces of conspecifics using 2D photos. However, we cannot conclude that pigs are unable to discriminate between faces of conspecifics using real pigs, because pictures vary from the real world in different ways.

From the results of this experiment, we can neither conclude whether pigs see pictures as representations of other pigs or not, although we have some indications (behavioural observations) that they do. We cannot draw conclusions about pigs' ability to form a concept of another individual; maybe pigs do form a concept, but using other cues such as olfactory or auditory. Jensen (2002)¹ points out that pigs use olfactory cues for individual recognition.

In this experiment we established a training limit of 289 trials. We could have continued training for some more sessions; in the end the pigs might have learned the task. However, after so many trials, there was still no indication that the pigs used the visual cues to find the reward. Although this finding cannot be directly generalized to their behaviour in the group, it questions whether pigs use vision in their daily life for individual recognition: if encountered with a new pig they have to learn to recognize it fast. In the first experiment we already experienced that pigs do not easily learn to associate a visual stimulus with food or discriminate between visual stimuli. This contrasts with the results of photo experiments with sheep and cows^{37, 38}.

Sheep learned to discriminate faster between faces than between geometric pictures³⁹. We hypothesized that this might also be the case with pigs, which are also animals that live in groups. Though, it seems that for pigs faces are not 'special', like for sheep; sheep have neural circuits in the temporal cortex that respond selectively to faces. These face-selective responses are influenced by different factors, such as species, breed and familiarity. Some

cells discharge more in the presence of frontal views of sheep or monkeys whereas other cells have a preference for human and dog faces ⁴⁹.

It would be interesting to further investigate if pigs show recognition in the presence of live animals. The difficulty here is to exclude other factors than vision. McLeman *et al.* (2008) ⁴² tried to do this by ventilating air from an animal-free room and positive air-pressure. By means of a trace-gas it was examined if there was any cross-contamination and the effect was very small. Vocalizations were not masked, but a sound system was used to replay the sounds of the two stimulus pigs at four different locations around the test apparatus. In this experiment, two out of three piglets were apparently able to discriminate between pigs using only visual information. It might be possible that pigs learn better when using live and thus mobile stimuli or that they need whole bodies and behaviour in order to discriminate visually. However, sample size was very small in the experiment by McLeman *et al.* and there was no hard evidence that the pigs could not detect any odour.

Pig cognition

Referring to the general part of the introduction of this study, we do know some more about pig cognition and learning ability, however, a lot of questions remain unanswered. From this study, we know that personality or coping style may influence the way pigs learn a task. Why the pigs learned the visual discrimination tasks so slowly remains unclear, because pigs are considered as intelligent animals. For example, they use other pigs to find food ⁵⁰ and can discriminate between different time intervals ⁵¹. It has recently been reported that pigs are able to use a mirror to obtain food ⁵². We were, however, unable to replicate this finding (see report by Elco Mijdam).

With this study we could not 'lift up' pigs' status as intelligent animals, which can influence the way people think about pigs and their welfare ⁴. However, we have to know more about the way in which pigs use vision in learning and daily life to make conclusions about their learning ability. Maybe pigs learn better using olfactory or acoustic stimuli than using visual stimuli.

Conclusions

The results of this experiment show that birth weight does not affect learning ability in a visual discrimination task in pigs. Behaviour in the back test (number of vocalizations) correlates positively, but moderately with learning of a simple visual discrimination task involving one stimulus. Birth weight and behaviour in the back test (struggles) are negatively, but moderately correlated.

The results from the photo experiment show that pigs are not able to discriminate between conspecifics by means of 2D pictures.



Figure 28. The author and one of the piglets during weighing on day three

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Appendices

Table 5. The piglets used in the experiments and their birth weight.

Earnr. Piglet (Low birth weight)	Birth weight (g)	Earnr. Piglet (Normal birth weight)	Birth weight (g)	Date of birth	Mean birth weight litter (g)	Mean birth weight litter without (g)
5338	1715	5508	2840	27-3-2010	2216	2560
5691	1230	5260	1880	25-3-2010	1725	1815
5040*	710	5599	2450	29-3-2010	2047	2433
5751	1385	5302	2430	27-3-2010	2111	2285
5209	1310	5637	1915	27-3-2010	1860	2064
5137	1120	5648	1585	26-3-2010	1569	1604
5439	1200	5078	2100	25-3-2010	1932	1999
5307	1300	5445	1790	26-3-2010	1701	1763
5010	1150	5240	1710	2-4-2010	1578	1762
5315	1295	5394	2115	1-4-2010	1912	2111
5308	1110	5052	1900	6-4-2010	1666	1961

The ear numbers of the piglets used in the experiment and their birth weights are shown in the 1st four columns. Piglets in the first column had a low birth weight; piglets in the third column had a normal birth weight. 'Mean birth weight of the litter' shows the mean birth weight of the litter including all piglets. 'Mean birth weight without' is the average birth weight of the litter without the low birth weight piglets. Piglet number 5040 died shortly after starting the habituation phase.

Table 6. Results of the back test done with four reserve piglets

Earnr.	Group	Birth weight (g)	Nr. of struggles	Latency (s)	Nr.of vocals	Latency (s)
5307	L	1300	3	1	0	28
5445	N	1790	1	50	21	10
5137	L	1120	0	60	2	0
5648	N	1585	2	20	43	0

The first latency is the latency to struggle and the second is the latency to vocalize. The 'L' in group means Low birth weight and 'N' means normal birth weight. A latency of 60 s means that there were no vocalizations or struggles.

Table 7. Results of the back tests of the piglets used in the visual discrimination task

Piglet nr.	Earnr.	Group	Birth weight (g)	Nr. of struggles	Latency (s)	Nr. of vocalisations	Latency (s)
1	5338	L	1715	1	57	14	1
2	5508	N	2840	0	60	11	3
3	5691	L	1230	2	34	50	0
4	5260	N	1880	2	0^	38	0
5	5751	L	1385	1	0	23	0
6	5302	N	2430	1	12	41	0
7	5439	L	1200	4	28	16	0
8	5078	N	2100	2	30	19	1
9	5010	L	1150	2	23	13	25
10	5240	N	1710	2	0	20	0
11	5308	L	1110	1	17	16	0
12	5052	N	1900	0	60	2	0
14	5599	N	2450	2	43	14	11
15	5315	L	1295	5	0	63	0
16	5394	N	2115	2	13	32	0
17	5209	L	1310	2	12	6	12
18	5637	N	1915	3	0	16	0
13*	5040	L	710	5	0	19	0

The first latency is the latency to struggle and the second is the latency to vocalize. The 'L' in group means Low birth weight and 'N' means normal birth weight. A latency of 60 s means that there were no vocalizations or struggles. Piglet number 13 died shortly after starting the habituation period.

Table 8. Number of trials in shaping phase and for session 1-5 the average percentage correct, alternations, choices right, left and longest series

Pig/group	% Correct	% Alternations	% Right	% Left	% Longest series
1 L	59,4	62,2	52,6	47,4	31,4
2 N	60,0	37,4	46	54	44
3 L	68,0	51,2	44	56	40
4 N	60,0	48,8	34	66	44
5 L	68,0	44,6	68	32	50
6 N	62,0	60,2	50,7	49,3	42,4
7 L	52,0	44,4	66	34	52
8 N	62,0	49,8	68	32	42
9 L	61	49,6	64	36	54
10 N	50,0	0,0	0	100	100
11 L	57,4	40,8	49,3	50,7	40,7
12 N	56,4	36,9	40	60	29
14 N	57,3	35,4	36,7	63,3	36,9
15 L	56,4	32,5	24,9	75,1	62,9
16 N	55,5	29,1	42	58	56
17 L	56,6	35,0	26	74	50
18 N	56,4	33,8	48	52	52

In the second column the number of trials is shown till reaching the criterion of learning. Piglet nr 11 reached this criterion in 3 sessions, but it was decided to continue training with her. Piglet 11 and 16 returned to the shaping phase when they were already in the training phase (see Materials and Methods). Number of trials in shaping phase shown here for piglet 11 and 16 are the number of trials till criterion of learning when they were for the first time in the shaping phase. The third column shows the mean percentage correct in the first 5 sessions of the shaping phase. The fourth column shows the mean percentage of alternations in the first 5 sessions. The fifth and sixth column show the mean percentages the piglet chose the right or left side of the test apparatus in the first 5 sessions. The last column shows the longest series of consecutive trials the piglet went left or right the first 5 sessions.

Table 9. Average percentage correct, alternations, choices right and left and longest series for sessions 6-10

Piglet/group	% Correct	% Alternations	% Right	% Left	% Longest series
1 L	57	62	58,7	41,3	32,7
2 N	48,8	79,4	42,7	57,3	20,4
3 L	60,7	66,4	50	50	24
4 N	54,0	78,0	44	56	22
5 L	52,0	80,2	54	46	24
6 N	46,8	88,4	44,7	55,3	16,4
7 L	51,2	68,4	46,7	53,3	24
8 N	52,9	76,3	62	38	24
9 L	51,4	78,3	54	46	28
10 N	50,9	78,3	38	62	54
11 L	50,6	77,9	50	50	22,7
12 N	51,4	75,8	48	52	28,7
14 N	51,5	77,3	48	52	18,7
15 L	51,2	77,5	42	58	32
16 N	51,1	77,4	51,1	48,9	24,4
17 L	51,2	77,2	36,7	63,3	24,7
18 N	55,0	58,2	37,3	62,7	34,7

Table 10. Average percentage correct, alternations, choices left, right and longest series for sessions 11-15

Piglet/group	% Correct	% Alternations	% Right	% Left	% Longest series
1 L	60,0	71,0	66	34	26
2 N	62,0	75,8	52	48	26
3 L	61,9	68,7	49,3	50,7	29,1
4 N	40,0	83,4	51,1	48,9	19,1
5 L	42,0	88,4	54	46	18
6 N	54,6	65,0	49,6	50,4	29,6
7 L	45,2	80,2	48,2	51,8	19,3
8 N	48,7	77,1	58	42	22
9 L	46,1	78,8	54	46	18
10 N	47,3	77,9	52	48	30
11 L	48,4	75,8	49,6	50,4	43,6
12 N	47,2	78,0	58	42	26
14 N	47,5	77,5	45,8	54,2	25,1
15 L	47,3	77,6	54,9	45,1	29,6
16 N	47,5	77,4	46	54	32
17 L	47,6	77,3	38,7	61,3	33,7
18 N	47,4	77,6	42,2	57,8	43,1

Table 11. Number of trial until criterion of learning in the training phase and the reversal

Piglet	Nr. of trials shaping phase	Nr. of trials training phase	Nr. of trials reversal
1	446	30	360
2	230	100	418
3	480	210	
4	540	298	
5	289	30	180
6	375	80	429
7	360	110	420
8	240	120	390
9	495	140	110
10	170	90	260
11	186 ^{^*}	20 [*]	370
12	234	100	256
14	385	140	
15	615	264	
16	216 [*]	20 [*]	
17	216	110	294
18	252	170	319

Orange cells mean that piglet did not reach criterion of learning in that particular phase; 'number of trials' is the number of trials till the end of the experiment in that cases. Numbers with an * mean that those piglets returned from training phase to shaping phase and after learning that, they continued learning the training phase. Number of trials in training phase shown for those piglets is the second time in the training phase. Piglet number 14 was excluded after holiday break, so data is not shown.

Table 12. Piglets and their weights

date	15-6-2010	8-7-2010	3-9-2010	2-11-2010
Piglet	Weight (kg)	Weight (kg)	Weight (kg)	Weight (kg)
1	29	42	76	107
2	30	44	78	109
3	28	42	74	105
4	37	53	95	130
5	24	35	66	95
6	34	49	91	123
7	23	35	66	91
8	32	46	79	113
9	20	32	64	90
10	21	31	55	78
11	20	33	68	100
12	26	40	78	109
14	34	52	97	129
15	19	30	61	85
16	31	47	93	123
17	19	29	60	83
18	30	44	86	123

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