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Pigs learn what a mirror image represents and use it to obtain information

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ABSTRACT

Mirror usage has been taken to indicate some degree of awareness in animals. Can pigs obtain information from a mirror? When put in a pen with a mirror in it, young pigs made movements while apparently looking at their image. After 5 hours spent with a mirror, the pigs were shown a familiar food bowl, visible in the mirror but hidden behind a solid barrier. Seven out of eight pigs found the food bowl in a mean of 23s by going away from the mirror and around the barrier. Naïve pigs shown the same, looked behind the mirror. The pigs were not locating the food bowl by odour, did not have a preference for the area where the food bowl was and did not go to that area when the food bowl was visible elsewhere. To use information from a mirror and find a food bowl, each pig must have observed features of its surroundings, remembered these and its own actions, deduced relationships among observed and remembered features and acted accordingly. This ability indicates assessment awareness in pigs. The results may

have some effects on the design of housing conditions for pigs and may lead to better pig welfare.

Keywords: awareness, cognition, learning, mirror, pigs,

INTRODUCTION

The E.U. Treaty of Amsterdam refers to domestic animals as sentient and a sentient being has been defined as "one that has some ability: to evaluate the actions of others in relation to itself and third parties, to remember some of its own actions and their consequences, to assess risk, to have some feelings and to have some degree of awareness" (Broom 2007). Hence the extent to which an animal can learn about complex aspects of its world and the level of awareness which it has can influence human attitudes to the moral status of such animals and hence the ways in which they are treated (Mendl et al 2001, Broom 2003).

Griffin (1981) said that awareness involves the experiencing of inter-related mental images and awareness has been defined as "a state in which complex brain analysis is used to process sensory stimuli or constructs based on memory" (Broom 1998). The term "complex brain analysis" implies that there is some degree of interpretive thought over and above perceptual processing and a gradation has been proposed with four categories of awareness: unaware but responsive, perceptual awareness, cognitive awareness, assessment awareness and executive awareness (Sommerville and Broom 1998). For example, in assessment awareness the individual is able to assess and deduce the significance of a situation in relation to itself over a short time span. The individual would not only be sensible to stimuli but would have memory of events and mental images of non-current events that could be used when taking appropriate action, both to avoid the negative and to increase positive consequences. This use of the concept of awareness is similar to that of Snyder et al (2004) who refer to awareness of concepts and equate consciousness with executive awareness. Mendl and Paul (2004, 2008) discuss "basic awareness" of sensations, feelings, emotions and memories. One level of self-cognition is to be self-referent and to discriminate labels of self from labels of non-self (Hauber and Sherman 2001) and this has been described as different from being self-aware "the cognitive process that enables an individual to discriminate between its

own body or possessions from those of others" Bekoff and Sherman 2004). However, this is a description of a consequence rather than a definition of self-aware as an individual could be self-aware in the absence of any cue from others. Most discussions of awareness refer to the social context and to whether animals are able to infer the mental states of others (Gallup 1998).

A prediction if an individual can have assessment awareness is that if it has a novel visual experience, like viewing images in a mirror, this could be followed by learning about what it sees in the mirror in relation to itself and then using such information at a later time. Human infants can use mirrors in the course of shape discrimination (Itakura and Imamizu 1994) and, if given sufficient exposure to mirrors at appropriate age, will discover the contingency between visual and proprioceptive feedback from their own body movements (Lewis and Brooks-Guy 1979). At five months of age they look more at their own image in a mirror than at the image of another infant or a puppet (Bahnick et al 1996) and at nine months they are able to discriminate self from other in a mirror (Rochat and Striano 2002). At 14-18 months, when looking in a mirror infants are described as showing self-referencing activities, self-labeling and embarrassment at rouge on the face (Bertenthal and Fisher 1987). These children would have been told that the image in the mirror is of themselves. Povinelli et al (1996) allowed children to see a television image of themselves, very similar to a mirror image, and found that when a sticker was put on their head, no 2-year-olds reached for the sticker, 25% of three-year-olds reached for it and 75% of 4-year-olds reached for it. Also using live television images, Menzel et al (1985) reported that chimpanzees could use these images to find targets visible only on the television screen. Iriki et al (2001) observed that Japanese monkeys could use televised images of their hands to pick up food while Anderson et al (2009), showed live television images of themselves to capuchin monkeys and concluded that their behaviour strongly suggested recognition of the correspondence between kinaesthetic information and external visual effects. Dolphins have been reported to use a television image, apparently to explore themselves visually (Marten and Psakoros 1995). Tests with chimpanzees, an elephant, dolphins and magpies that had had previous experience of mirrors, using marks on the body visible in a mirror, led to the individuals touching or apparently looking at the marks (Gallup 1982, Reiss and Marino 2001, Plotnik et al 2006, Prior et al 2008).

The abilities indicated by these mirror and television image studies range from discrimination of images, through learning that what is seen in a mirror is on the same side as the observer, learning that own movements can be monitored by looking at the mirror, to appreciating that the image is the self. As Rochat (2002) puts it, in this last case the specular image is standing for the identified or conceptual self, not somebody else, and the self is as seen by others.

Pigs have complex social behaviour (Jensen 1982, Broom and Fraser 2007) and a series of experimental studies have also provided evidence of their substantial cognitive ability (Mendl et al 1997, 2001, Croney et al 2003, Laughlin and Mendl 2004, Held et al 2005). For example, pigs can recall where food was encountered, integrate this information with information about type of food and replenishment rate and avoid unproductive visits to potential food sites (Mendl and Paul 2008). The present study was designed to find out whether or not pigs could use information from a mirror to locate an object that could only be seen in the mirror. Pigs which had not had experience of a mirror were compared with pigs which had.

The vision of pigs is adequate for mirror images to be perceived and eyeball size, retina, pupil and lens are similar to those of humans (Piggins 1992, Zonderland et al 2007). Pigs have fewer cone cells than humans so their spatial discrimination is poorer (Zonderland et al 2007). However they show preferences for food bowls of certain colours (Deligeorgis et al 2006). Olfactory signals are used for social recognition and regulation of sexual behaviour but pigs can successfully find food sources using visual or olfactory cues (Kristenson et al 2001, Croney et al 2003, Zonderland et al 2007).

In a preliminary study the behaviour of pigs was recorded when they first encountered a mirror and after 24 hours with it. The response of pigs naïve to a mirror was then compared with pigs with five hours experience of a mirror when they saw a food bowl reflected in the mirror. The distribution of time in different parts of the test pen prior to seeing the food bowl in the pen was also observed in separate trials. In a subsequent test, the mirror was replaced by wire-mesh with the food in the position visually the same as when the mirror was present.

METHODS

The subjects were 4-8 week Large White x Landrace pigs housed in strawed pens with natural light and food and water *ad libitum*. All were familiarised with a red food

bowl as a food container. None had seen a mirror, or other reflecting surface, before the studies described here.

The trials took place in a 4.6 x 2.8 m. strawed pen located approximately 30 m away from the home pen. All behaviour was video-recorded. The 0.6 x 0.7 m. mirror was in a 1.2 x 1.4 m. frame. A 1.7 m. long 1.4 m. high barrier could be attached to the mirror frame, 0.09 m. from the mirror, so the pig couldn't pull it and pass between it and the frame (Fig. 1). In the preliminary study, seven pigs were put individually into the pen for 24 hours with the mirror and food present. Their behaviour was recorded for the first two hours and from 23 to 24 hours.

During the trials with the mirror and food bowl (Mirror Test), the pig was put in a small pen (area 7) with solid wooden walls. A curtain covered the exit from the small pen so that the pig could not see outside it. The curtain was opened and the pig left inside this small pen for 1 minute before the front gate of the small pen was opened with a pulley to allow the pig to leave. During the minute before the gate was opened in the Mirror Test the pig could see the barrier and the right hand side of the mirror with the image of the food bowl through the front section. When in Area 4 or Area 7 the pig could see the food bowl but could not see whether or not there was food in it.

Fig. 1 Plan of the pen where the experiments were carried out, showing the small pen with solid walls (area 7), mirror (or wire mesh) in a frame, solid wood barrier, fan position (above pig head level in the pen) and the numbers of floor sections used to describe the position of the pig. Area 3 is where the red food bowl, whose reflection was visible in the mirror when the pig was in areas 4 or 7, was placed during the mirror test. The food bowl would appear to be in area 1 to a naïve pig that had not had experience with a mirror.

The mirror tests were carried out during nine non-consecutive weeks between 09.00 and 18.00 hours. Firstly, pigs with no previous experience of a mirror were tested, then pigs that had experience with a mirror.

Eleven "mirror naïve" pigs, six males and five females, which had never seen a mirror were released, singly, into the pen (Fig. 1) with the red food bowl, containing food, present on the left side of the barrier and visible only in the mirror. A fan was positioned slightly behind and above the food. This was intended to ensure that the smell of the food could not be localised by the pig. Observation of the movement of particles in the air indicated that air flowed initially from the front towards the back of the pen but then became mixed throughout the pen. The behaviour of the pigs was recorded during the Mirror Test with the intention of continuing for one minute or, if it occurred earlier, until the pig moved behind the barrier or mirror. Each of the 11 pigs was observed in the Mirror Test once and not used in any subsequent test.

In order that the "mirror experienced" would have the opportunity to learn about a mirror, eight pigs, four females and four males, were put into the pen with a mirror in it for 5h. They were in pairs, so that they would not associate the visits to the pen with social isolation. This provided company but also allowed them to observe the other animal as a moving reference point in the mirror. The subsequent tests, described below, were conducted on the same day.

In order to find out where the "mirror experienced" pigs would go by chance in the test pen after leaving the small pen, two males and two females were observed. Only four of the eight pigs used in the Mirror Test were used because the desirability of this control study was only appreciated after the first four pigs had been tested. They were left in the small pen for 15 s and then allowed to go out of it for 25 s. The barrier and mirror were

in place but no food or food bowl was present. The amount of time spent in areas 1 to 7, including area 1 behind the mirror and area 3 where the food was located in the mirror test, was recorded.

The Mirror Tests were done once with each of eight "mirror experienced" animals using the pen shown in Fig. 1. The bowl with food was placed on the left side of the barrier in such a way that it could be seen from the small pen via the mirror. Each pig was in the Area 7 pen and then released, as explained above. After release it was left in the test pen for a maximum of one minute and its behaviour video-recorded.

After the "mirror experienced" pigs had completed the Mirror Test, in order to check whether the pigs had just changed their behaviour to show a preference for Area 3 (behind the barrier) wire mesh of mesh diameter approximately 3 cm was put in the frame in place of the mirror. The food in the food bowl was put behind the frame so the pig could see it through the wire mesh in the same position that a mirror image would appear to have. The same methodology was used in the Wire-Mesh Test as in the Mirror Test for each of the eight pigs. In an extra, subsequent test, with only the last of the pigs previously tested, wire-mesh was in place of the mirror, the familiar bowl behind the wire-mesh was clean and empty and there was food in a bowl on the other side of the barrier, i.e. in the place where the food was put in the Mirror Test.

RESULTS

Initial observations: qualitative descriptions of first contact with the mirror

When first encountering the mirror, all seven pigs whose behaviour was recorded in detail walked towards it, sometimes vocalising, stopped with nose pointing towards the mirror, moved forward again and made contact with the mirror surface with their nose. Some pigs looked behind the mirror after looking at their reflection in it. One female pig, observed during preliminary studies, moved rapidly towards the mirror and broke it, perhaps attacking her mirror image. After initially encountering the mirror the pigs moved back from the mirror surface, oriented nose and eyes towards it apparently looking at it and made movements looking again from different angles. Three pigs

showed some weaving movements. In the preliminary studies, the mean time before there was a break of more than 30s in attending to the mirror was 20 minutes. Some habituation to the mirror was apparent and from 23 to 24 hours after the mirror was put in the pen, much less time was spent looking at it than in the first hour. Similar behaviour was shown during the 5h exposure to the mirror by the pigs that would experience the Mirror Test. Sometimes pigs lay down in front of the mirror, looking at it or in parallel with it as if lying beside another pig.

"Mirror naïve" pigs in the Mirror Test.

Of the eleven pigs that had never seen a mirror, in the Mirror Test where they could see a familiar food bowl reflected in a mirror, but not directly visible because it was behind the barrier, nine approached the mirror then walked behind it to area 1 (Table 1). One pig knocked over the barrier and one walked around the whole pen including going behind the barrier. In each case, the trial was then terminated. The nine pigs that went behind the mirror did so in 15-50 seconds (mean 25.7, s.d. 11.6).

"Mirror experienced" pigs: activity in Mirror Test pen prior to Mirror Test.

The animals observed were able to go anywhere in the test pen for 25s with no food present, so the total time, during four repeats for 4 animals, was 400 seconds. In the 16 periods, Area 1 was visited by three pigs on one occasion each whilst Area 3 was visited by four pigs on one occasion each as the pig walked around the pen. The total time spent in Area 3 was 66s (mean per individual 16.5s, S.D. 9.8). The 66s spent in Area 3 out of a total time observed of 400 s gives a probability of one in six of a pig in this pen being in Area 3 at any one time and a probability of one in four of visiting Area 3. A statistical comparison with Mirror Test data is not accurate because some cell sizes are too small.

"Mirror experienced" pigs in the Mirror Test.

When the eight pigs with previous experience of the mirror were released from the small pen during the Mirror Test, they walked out, looked around the test pen and looked at the mirror where the food dish was visible. Seven of the eight pigs went to Area 3 on the left side of the barrier and reached the food (Table 1). They all moved away from the mirror, around the end of the barrier, and then directly to the food. The

times taken to reach it were 11s, 29s, 23s, 10s, 46s, 13s, 32s, mean 23.4 s, S.D. 13.3s. One pig took 41s to decide and then went to Area 1 behind the mirror. For comparisons of the numbers of naïve and experienced pigs reaching Area 1: $p<0.01$ and Area 3: $p<0.01$ (Fisher Exact Test).

Table 1. Comparison of "Mirror naïve" and "Mirror experienced" pigs in the Mirror Test and Wire-Mesh Test.

	"Mirror naïve"	"Mirror experienced" Mirror present	"Mirror experienced" Wire-Mesh present
n	11	8	8
Number going to:			
Area 1 (behind mirror)	9	1	6
Area 3 (with food bowl)	1	7	2
Other action	1		
Mean latency if reached Area 1		41s (n=1)	14s SD 3.9s
Mean latency if reached Area 3		23s SD 13.3s	43s (n=2)

"Mirror experienced" pigs in the Wire-Mesh Test.

In this test, conducted after the Mirror Test, six of eight pigs went to Area 1, behind the wire-mesh frame, and reached the food (Table 1). Of the two pigs that went to Area 3, one took 44s to decide and was the individual that did not reach the food in the Mirror Test, whilst the other took 42s to decide before going to the wrong place. Both showed frequent hesitation when moving. Comparing 6 out of 8 pigs going to Area 1 with 1 out of 8 in the Mirror Test, $p < 0.01$ (Fisher Exact Test). In the test on a single pig with an empty bowl behind the wire mesh and a full food bowl behind the barrier, the pig went behind the mirror to the empty bowl in Area 1.

DISCUSSION

285 The aim of this study was to find out whether or not pigs can obtain information from
286 a mirror, as has been demonstrated for humans and other primates, dolphins, elephants,
287 magpies and an African grey parrot (Pepperberg et al 1995). The 4-6-week-old pigs
288 studied responded to a mirror initially as if to another pig but later by looking at it as
289 they moved. They moved and then stopped still, apparently looking at their image and
290 its surroundings, oriented either with nose towards the mirror or with the head parallel
291 to it. As a consequence of the lateral position of the pig's eye, it is not possible to record
292 duration of looks towards the mirror and pigs show little change in facial expression.
293 They do vocalise and some of these pigs did so when exposed to the mirror. As with the
294 movements in front of a novel mirror described for chimpanzees, humans, capuchin
295 monkeys, dolphins and elephants (Gallup 1982, Reiss and Marino 2001, Keenan et al
296 2003, Plotnik et al 2006, Anderson et al 2009) some of the movements of these young
297 pigs suggest that they could have been monitoring the movements in the mirror image
298 when they moved their own head or body. As Anderson et al (2009) put it, the animals
299 could be comparing the kinaesthetic information and the external visual effects.
300
301 Although the naïve pigs exposed to the Mirror Test went behind the mirror to the
302 apparent position of the food bowl, five hours experience with the mirror in a pen
303 changed the behaviour of the pigs. When they were subjected to the Mirror Test, all but
304 one of them went away from the mirror to the actual position of the food bowl within
305 23s. This movement is first with the air-stream, then against it. The results in total, in
306 particular the difference between the naïve and mirror-experienced pigs, makes it clear
307 that the pigs were not locating the food bowl by odour. Pigs often use smell to reach
308 food (Zonderland et al 2007), but the fan blew air away from the food bowl and
309 circulated it in the pen. The single pig in the Wire Mesh Test that could see a bowl
310 through the wire mesh but could not see that the bowl was empty went to the empty
311 bowl rather than to a bowl containing food behind the barrier. It would seem that
312 localisation of the food bowl when the fan was on was impossible, or at least more
313 difficult than using the visual information. The association between visual cues and
314 food reward is sometimes not an easy task for pigs (Zonderland et al 2007) but it seems
315 that they learned how to do so in this study. They also learned in five hours to use the
316 mirror in a way that later allowed them to locate the food. In the Mirror Test, "mirror
317 experienced" pigs went to the position of the food behind the barrier in Area 3 much

more often than had four of their number, after mirror experience but prior to the Mirror Test, when their activity was monitored in the Mirror Test pen with no food in it.

The possibility that all pigs had developed a preference for Area 3 at the time of the Mirror Test was shown not to be the case when the same animals were tested soon afterwards with the wire-mesh in place of the mirror (Wire-Mesh Test) and six out of eight went to the food bowl behind the wire mesh in Area 1. One pig went to the wrong side in both trials, behind the mirror (Area 1) in the Mirror Test and to the left side of the barrier (Area 3) in the Wire-Mesh Test. This animal either could not learn, or did not have enough time to learn, about a mirror as it was confused in both trials, taking 41 s and 44 s respectively. Another pig, which reached the food in the Mirror Test but not in the Wire-Mesh Test, also seemed to be confused in the latter and took 42 s to decide to go to the left side of the barrier (Area 3) instead of the back of the frame where the food bowl was located.

A reflecting surface, such as the mirror, was novel to the pigs studied and changes in their behaviour were apparent when they were exposed to the mirror. Each of the seven pigs that used information from the mirror and rapidly found the food bowl must have: observed features of its surroundings, remembered these and its own actions, deduced relationships among observed and remembered features, and acted accordingly. When a mirror-experienced pig saw the food in the mirror, it could not smell the food directly, although it was likely to be able to detect the presence of food throughout the test period.

The pig has looked at the mirror and appreciated that what it sees is related to its own movements and that the image reveals objects that are not directly visible and that have an actual position that has a certain relationship with where they appear to be. When it looked at the red bowl and then turned away from the mirror to go around the barrier, it must have remembered that the mirror image gives information about what is positioned somewhere to the left of perpendicular to the mirror surface. The action of turning away from the mirror and going behind the barrier to reach the food bowl necessitates remembering the position of the food while it is navigating around the barrier. The concept of the food and its position must be remembered while it is carrying out the

351 actions to get to the food. Some kind of map of its environment and awareness of its
352 movement ability is needed to do this. The behaviours and ability shown fulfil the
353 criteria described above for assessment awareness (Sommerville and Broom 1998).

354 In studies of human infants, and in most studies of other Primates, with mirrors or
355 television self images, the subjects had prolonged experiences of the images. Human
356 subjects are generally given much information about mirror images and television
357 images by their parents and others. The pigs in this study had only five hours of
358 experience of a mirror before they demonstrated that they could use information from it.
359 However, no test for self-recognition has been conducted on pigs. Just as in other
360 studies, e.g. that of Paukner et al (2004) with capuchin monkeys, information from a
361 mirror or television self-image does not necessarily imply awareness by the subject that
362 the image is that of itself.

363 Work with various species of animals indicates that the presence of a mirror or
364 television image may add complexity to the environment of an individual and improve
365 its welfare (Plattner and Novak 1997, McAfee et al 2002). These abilities of pigs, and
366 the awareness indicated by them, may result in some people housing and treating pigs
367 better than previously, so that poor welfare is minimised. The relationship between the
368 cognitive ability of animals, sentience and how they should be treated is discussed by
369 Mendl et al (2001), Broom (2003, 2007), Panksepp (2005), Webster (2006).

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374

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Lay summary (150 words).

How clever are pigs? We tested whether pigs can learn that what they see in a mirror is in front of it in a certain position and not behind it. Young pigs, shown a mirror for five hours, moved while apparently looking at their image. Afterwards, the pigs were shown a familiar food bowl, visible in the mirror but hidden behind a solid barrier. Seven out of eight pigs rapidly found the food bowl by going away from the mirror and around the barrier. Naïve pigs shown the same, looked behind the mirror. The pigs were not locating the food bowl by odour and did not have a preference for the area where the food bowl was. In order to be aware of the food bowl position, each pig must have learned how to use a mirror image. Views about pig management and welfare may be changed by such results.

For version with Figure contact authors.

Figure 1. Plan of the pen where the tests were carried out, showing the small pen with solid walls (Area 7), mirror (or wire mesh) in a frame, solid wood barrier, fan position (above pig head level in the pen) and the numbers of floor sections used to describe the position of the pig. Area 3 is where the red food bowl, whose reflection was visible in the mirror when the pig was in Areas 4 or 7, was placed during the Mirror Test. The food bowl would appear