Do young domestic pigs (*Sus scrofa domestica*) rely on object-specific cues in a simultaneous discrimination task?

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Abstract

Finding and relocating food sources is not only crucial for individuals in changing natural environments - it is also of importance in domestic animals under husbandry conditions, for instance to reduce stress when transferring animals into new housing conditions. This study makes a first attempt by investigating young pigs´ use of conflicting spatial and feature cues in a simultaneous discrimination task. In a training phase, subjects (*n* = 9) first learned to approach a food container with distinct spatial and feature cues. In a subsequent test phase, spatial and feature cues were brought into conflict. Results show that young pigs significantly preferred to approach the spatial position rather than the feature cue of a food container – at least for the visual domain - while inter-individual differences in choice behaviour suggest that animals recognized the changed context. However, the actual test setup did not exclude alternatives to the use of spatial cues, e.g. instrumental learning. The results may contribute to a better understanding of learning mechanisms in domestic pigs and could be used to improve husbandry designs, reduce stress levels after transfer and may prove to be helpful in designing further test paradigms investigating discriminative learning abilities in the domestic pig.

Keywords: domestic pig; spatial memory; feature cues

Introduction

Finding and memorizing food patches is essential when making foraging decisions. However, there are different possible strategies to achieve this goal – for instance by remembering distinct features of the patch like size and colour, or by spatially representing the environment, using local or global landmarks or the inter-array constellation of specific objects (Shettleworth, 2010). Studies in which those cues were brought into conflict showed strong species-specific differences that most likely reflect the species´ eco-ethological niche. Species that forage on visually distinct and irregularly scattered food sources should have an advantage to rely more on feature cues than on spatial position while relocating a food patch - which has been shown for great apes as well as for chicken (Kanngiesser & Call, 2010; Vallortigara & Zanforlin, 1989). When food sources are not visually distinct or not even visible (i.e. located beneath the surface), animals should prefer a spatial strategy. Vlasak (2006) found that ground squirrels preferentially use, if available, a learned familiar route and global landmarks (but see Waisman and Jacobs (2008) for fox squirrels). Particular behavioural traits can also lead to differences in cue use. When recovering a reward, food storing birds rely first on spatial cues during their search behavior and start to use feature cues when their first attempt was not successful. Non-storing species, however, use both cues types equally (Brodbeck, 1994; Clayton & Krebs, 1994).

Several studies showed that pigs seem to be exceptionally good in using spatial information to find hidden food (Mendl et al. 1997; Laughlin and Mendl 2000; Bolhuis et al. 2013). However, they are also able to use feature cues like colour or odour to relocate a rewarded option (Croney, Adams, Washington, & Stricklin, 2003; Gieling, Musschenga, Nordquist, & van der Staay, 2012). In particular, Croney and colleagues (2003) provided micro pigs with multiple cues (spatial, vision, olfactory) in training sessions and found that pigs in test sessions were able to learn to use visual and olfactory object-specific cues to navigate. However, since no first-trial results are reported, it is not clear if subjects had first to overcome a primary learned spatial position or if they choose randomly.

In this study, we wanted to further investigate the role of spatial and feature cues in foraging decisions by testing young domestic pigs in a simultaneous discrimination task. For domestic pigs as farm animals, information on spatial learning mechanisms could be used to improve husbandry conditions (e.g. positioning and design of feeders) or reduce stress levels of pigs after transfer into new housing environments by providing them with cues that facilitate recognition of previous housing conditions based on preferences and previous experience. Subjects had to learn the location of a reward through distinct spatial and feature cues. In a subsequent test, spatial and feature cues of the reward were brought into conflict. Due to pigs´ rooting foraging behaviour they find a high amount of food below the surface and we therefore expected a high prevalence for the learned spatial position. However, individual analysis could shed a light on whether subjects developed inter-individual differences in their choice behavior.

Materials & Methods

Subjects

The study involved 12 pigs [[DExDL]xPi] - seven males and five females - at the age of seven weeks. All individuals were reared at the research facility. Pigs had access to a commercial diet ad libitum. Water was provided from nipple drinkers in the home pens at all times. Procedures and housing of experimental animals on our University Research Centre in Merbitz were licensed under the veterinary board order Nr. 152650330021. Housing facilities met the German welfare requirements for farm animals.

Housing

Pigs were socially housed in a barn of the Institute of Agricultural and Nutritional Sciences in Merbitz, Germany. Temperature was maintained at about 23°C and artificial light was provided from 7 am to 5 pm. Pigs were housed as a group in a home pen (250 x 400 cm) on solid floor with straw bedding. Branches were used as additional enrichment material. The present study was conducted in March 2013.

Habituation

After transferring subjects to their home pen they received five days of habituation to reduce aggressiveness and to get familiar with the new environment. Every day, the experimenter (‘E’) entered the home pen for about 40 min. Subsequently, pigs received four days of habituation to a test area (see Figure 1) and an adjacent resting area before experiments began. During the first two days, they were introduced as a group for about 15 min to both areas. On the third and fourth day, they were introduced alone, again for about 15 minutes and could explore the areas on their own. Two individuals had to be excluded because they still showed signs of distress and arousal at the end of the habituation phase.

Initial Training

In an initial training phase, subjects had to learn to snout a yellow bucket (diameter: 28 cm, height: 28 cm) centered in the area and placed 100 cm away from the entrance to receive a reward (a pellet of commercial dog food) hidden beneath it. After the subject found the reward, it was slightly pushed to go back into the resting area and was then able to re-enter the test area. This was repeated 10 times in each session until subjects went straight to the bucket in all training trials in one single session. Training sessions were conducted once a day. The mean number of training sessions to reach this criterion was 2.67 ± 0.24 (Mean ± SEM). One individual refused to snout the bucket in all sessions and was therefore excluded. During the initial training, and as well for learning and test sessions, two identical black cylindrical nipple drinkers (diameter: 30 cm; height: 100 cm) were used as local landmarks, and were placed on the opposite side of the entrance with a distance of 150 cm between each other (see Fig. 1). Neither position nor features of the yellow bucket were identical to the ones used during learning and testing sessions.

Figure 1

Learning phase

Learning sessions were conducted once a day. Three buckets were positioned in the test area – two unrewarded red and tall buckets (diameter: 16 cm, height: 18 cm) and a rewarded blue and small bucket (diameter: 14 cm, height: 9 cm). For five subjects, the rewarded bucket was positioned on the left, for four subjects it was positioned on the right side (see Fig. 1). The buckets were arranged in a semicircle so that each bucket had the same distance towards the entrance (140 cm). The distance between buckets was 40 cm (see Fig. 1). Additionally, in the first learning session individuals received correction trials. That means that they could choose additional buckets if their former choice was incorrect. The learning criterion was set at 10 out of 12 correct choices of the rewarded bucket in one learning session (binomial test: P < 0.001). If a subject reached the learning criterion, it was transferred to the test phase on the following day. To ensure learning performance, every individual received four learning trials right before the test. If they chose correctly in all four trials, testing started. If they made one or more incorrect choices, the session was continued as learning session. To avoid potential odour learning, all buckets had a reward fixed with tape on their inside. The experimenter, who was kneeling behind the buckets, was watching down on the ground to avoid inadvertent cueing (Nawroth, Ebersbach, & von Borell, 2013).

Test phase

During testing, all buckets were baited with a food reward and the position of the former rewarded bucket (blue, small) was changed from the right to left position or vice versa, depending on the former learned location (see Fig. 1). Every subject received 12 successive test trials.

Data analysis

Individual´s choices in the learning and test sessions were scored live. For data analysis on group level, we used exact Wilcoxon-signed-rank tests to check whether subjects preferred one of the three offered options in the test above chance level (33%). For first choices and individual analysis, we used binomial tests. When a subject chose a specific option eight or more times out of 12 trials it was counted as significant (binomial test: P = 0.032, two-sided)

Results

Subjects (n = 9) as a group needed 1.56 ± 0.18 (Mean ± SEM) learning sessions to reach criterion to pass to the test procedure (see Table 1). Seven out of nine subjects chose the spatial option in the very first trial (binomial test: P = 0.016, two-sided), whereas only two did so for the feature option (binomial test: $P > 0.05$, two-sided). In the whole test session, pigs chose the spatial, but not the feature option, significantly above chance level (spatial: $Z = -2.144$; $P = 0.035$; feature: $Z = -0.564$; $P = 0.602$). In addition, choice of the middle option, which contained none of the former learned information, was below chance level ($Z = -0.816$; $P = 0.004$). Individual performances reflected the results of the group data, with five subjects choosing the spatial option significantly above chance level whereas only one individual did so for the feature option (see Table 1). Finally, we found no effect of sex or initially reward location in choice behavior at group level (exact Mann-Whitney-U-Test: $P > 0.3$ for all comparisons).

Table 1

Discussion

The results show that juvenile pigs highly preferred to approach the former rewarded spatial position rather than the feature cue. The choice on chance level of feature cues compared to the choice below chance level of the middle option, which contained no rewarded information at all, suggests that they recognized the changed context and were not only randomly choosing one of the options other than the formerly rewarded spatial position.

The actual test setup did not allow us to clarify if spatial position and feature cues compete for associability (Sánchez-Moreno, Rodrigo, Chamizo, & Mackintosh, 1999) or if both of the two cue types were encoded but used in a hierarchical manner. Though subjects relied less on object-specific cues, we cannot draw conclusions if pigs relied solely on spatial cues to find a reward. Alternatively, pigs may have been conditioned in an instrumental manner due to training trials and were simply orienting to the left or right when entering the test area. Additionally, they might have developed a win-stay/lose-shift strategy (Mendl et al., 1997; but see Laughlin and Mendl, 2000), as it has been described for a number of mammalian species (Olton, Handelmann, & Walker, 1981). Therefore, further studies should investigate pigs´ spatial learning strategies in more detail, for instance if they preferably use local or global landmarks, inter-array constellation, or mixed strategies to relocate a target object or if the perceptual modality and salience of a feature cue is of importance. Future setups should also differentiate between egocentric (response learning) and allocentric strategies (place learning) in relocating a food source (Bolhuis et al., 2013; Shettleworth, 2010). The age of the subjects may be another important factor. In humans, toddlers mainly use geometric information and switch to use feature cues from the age of six years on (Cheng & Newcombe, 2005; Hermer & Spelke, 1994) .

The results may contribute to a better understanding of learning mechanism in the domestic pig when multiple cues are present and could therefore be used to improve husbandry designs or reduce stress levels after transfer by providing them with cues in their new environment that they remember from previous housing conditions (Held, Mendl, Laughlin, & Byrne, 2002). Finally, the obtained results may prove to be helpful in designing further test paradigms investigating discriminative learning abilities and food finding strategies in the domestic pig.

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References

Bolhuis, E. J., Oostindjer, M., Hoeks, C. W. F., de Haas, E. N., Bartels, A. C., Ooms, M., & Kemp, B. (2013). Working and reference memory of pigs (Sus scrofa domesticus) in a holeboard spatial discrimination task: the influence of environmental enrichment. *Animal Cognition*, *16*, 845–850. doi:10.1007/s10071-013-0646-7

Brodbeck, D. R. (1994). Memory of spatial and local cues: A comparison of a storing and a nonstoring species. *Animal Learning & Behavior*, *22*, 119–133.

Cheng, K., & Newcombe, N. S. (2005). Is there a geometric module for spatial orientation? Squaring theory and evidence. *Psychonomic Bulletin & Review*, *12*(1), 1–23. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/15945200

Clayton, N., & Krebs, J. (1994). One-trial associative memory: comparison of food-storing and nonstoring species of birds. *Animal Learning & Behavior*, *22*(4), 366–372. Retrieved from http://link.springer.com/article/10.3758/BF03209155

Croney, C. C., Adams, K. M., Washington, C. G., & Stricklin, W. R. (2003). A note on visual, olfactory and spatial cue use in foraging behavior of pigs: indirectly assessing cognitive abilities. *Applied Animal Behaviour Science*, *83*(4), 303–308. doi:10.1016/S0168-1591(03)00128-X

Gieling, E. T., Musschenga, M. A., Nordquist, R. E., & van der Staay, F. J. (2012). Juvenile pigs use simple geometric 2D shapes but not portrait photographs of conspecifics as visual discriminative stimuli. *Applied Animal Behaviour Science*, (0). doi:10.1016/j.applanim.2012.10.018

Held, S., Mendl, M., Laughlin, K., & Byrne, R. W. (2002). Cognition studies with pigs: Livestock cognition and its implication for production. *J. Anim Sci.*, *80*(E-Suppl_1), E10–17. Retrieved from http://jas.fass.org/cgi/content/abstract/80/E-Suppl_1/E10

Hermer, L., & Spelke, E. S. (1994). A geometric process for spatial reorientation in young children. *Nature*, *370*, 57–59.

Kanngiesser, P., & Call, J. (2010). Bonobos, chimpanzees, gorillas, and orang utans use feature and spatial cues in two spatial memory tasks. *Animal Cognition*, *13*(3), 419–430. doi:10.1007/s10071-009-0291-3

Laughlin, K., & Mendl, M. (2000). Pigs shift too: foraging strategies and spatial memory in the domestic pig. *Animal Behaviour*, *60*(3), 403–410. doi:10.1006/anbe.2000.1468

Mendl, M., Laughlin, K., & Hitchcock, D. (1997). Pigs in space: spatial memory and its susceptibility to interference. *Animal Behaviour*, *54*(6), 1491–1508. doi:10.1006/anbe.1997.0564

Nawroth, C., Ebersbach, M., & von Borell, E. (2013). Juvenile domestic pigs (Sus scrofa domestica) use human-given cues in an object choice task. *Animal Cognition*. doi:10.1007/s10071-013-0702-3

Olton, D. S., Handelmann, G. E., & Walker, J. A. (1981). Spatial memory and food searching strategies. In A. C. Kamil & T. D. Sergent (Eds.), *Foraging Behavior: Ecological, Ethological, and Psychological Approaches* (pp. 333–354). New York: Garland STPM Press.

Sánchez-Moreno, J., Rodrigo, T., Chamizo, V. D., & Mackintosh, N. J. (1999). Overshadowing in the spatial domain. *Animal Learning & Behavior*, *27*(4), 391–398. doi:10.3758/BF03209976

Shettleworth, S. J. (2010). Getting Around: Spatial Cognition. In *Cognition, Evolution, and Behavior* (second., pp. 261–312). Oxford: Oxford University Press.

Vallortigara, G., & Zanforlin, M. (1989). Place and object learning in chicks (Gallus gallus domesticus). *Journal of Comparative Psychology*, *103*(2), 201–209.

Vlasak, A. N. (2006). Global and local spatial landmarks: their role during foraging by Columbian ground squirrels (Spermophilus columbianus). *Animal Cognition*, *9*(1), 71–80. doi:10.1007/s10071-005-0006-3

Waisman, A. S., & Jacobs, L. F. (2008). Flexibility of cue use in the fox squirrel (Sciurus niger). *Animal Cognition*, *11*(4), 625–36. doi:10.1007/s10071-008-0152-5

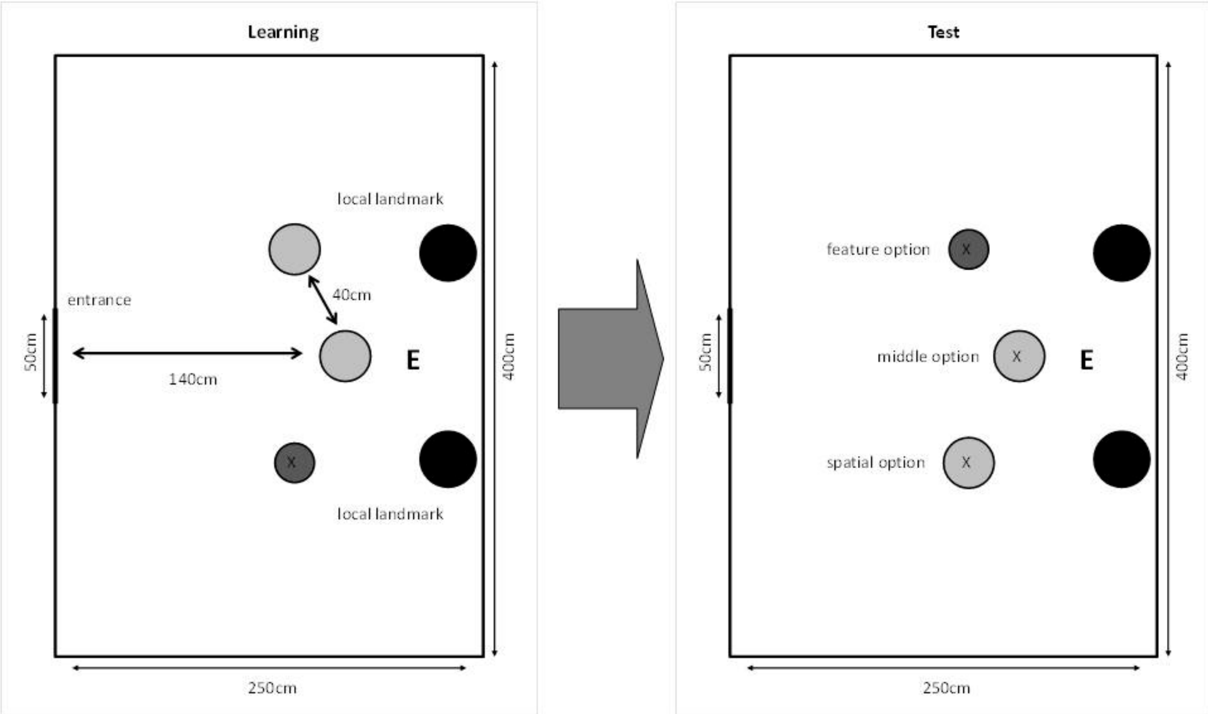

Figure 1 General setup of learning and test sessions. Three potential reward locations were positioned in a semi-circle in the test area. E = experimenter, x = hidden food reward

Table 1 Data on individual choice behavior. Scores in bold are significantly above chance level (P < 0.05).

Subject	Sex	Rewarded Position	Training	Learning	Choice of Place	Choice of Middle	Choice of Feature	First Choice
			# of Sessions	# of Sessions	Out of 12 trials			
A	F	right	2	1	**12**	0	0	place
B	M	right	3	1	6	0	6	feature
C	M	right	2	1	**9**	2	1	place
F	M	left	2	2	**12**	0	0	place
G	M	left	4	2	**8**	0	4	place
H	F	left	3	2	**12**	0	0	place
I	F	right	3	1	6	0	6	place
K	M	left	3	2	0	0	**12**	feature
L	F	left	2	2	7	0	5	place
Mean			2.67	1.56	**8.00**	0.22	3.78	
SEM			0.24	0.18	1.30	0.22	1.34	

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